Appendix A – Feasibility Study with Appendices (Phase I)
Feasibility of Recycled Polyethylene Terephthalate (PET) Carpet in Civil Engineering Applications

Grant Number: CCSP-1B-16-002B

Carpet America Recovery Effort (CARE)
FEASIBILITY OF RECYCLED POLYETHYLENE TEREPHTHALATE (PET) CARPET IN CIVIL ENGINEERING APPLICATIONS

GHD Project No. 11121650

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Executive Summary

California Assembly Bill 2398, which was established in 2010, designated Carpet America Recovery Effort (CARE) as the carpet stewardship organization, with oversight from the California Department of Resources Recycling and Recovery (CalRecycle). CARE currently administers the California Carpet Stewardship Program (CCSP). The goal of the CCSP is to provide funding to establish, increase, and improve the collection, recycling, and utilization of California-generated post-consumer carpet (PCC) in recycled-content product manufacturing. To-date, CARE has successfully created a program to support the collection and reuse of nylon carpet, which has traditionally made up a majority of the recycled carpet waste stream. However, waste polyethylene terephthalate (PET) carpet has significantly increased in recent years. PET carpet fiber is manufactured from recycled soda and water bottles. While the backing of the PET carpet is separated and manufactured into new products (similar to nylon-based carpet backing), an efficient and cost-effective use for the face fiber of recycled PET carpet (RPC) has not been developed. For this project, GHD was awarded funding to assess the feasibility of using RPC in civil engineering applications. Humboldt State University was retained by GHD to perform initial testing of the RPC material properties.

This feasibility study is the first phase (Phase I) to investigating and establishing a potential market for RPC. For this study, four different RPC products were tested: shredded carpet, face fiber, carpet underlayment, and powdered carpet backing. In order to understand how the material will perform in potential civil engineering applications, HSU performed laboratory analyses to determine the density, water holding capacity, compressibility, hydraulic conductivity, and porosity values for RPC. Additionally, the concentrations of selected constituents were determined for water-saturated RPC under various durations.

Leachate water quality results after a 1-month soaking period show that RPC material is relatively benign. Only 22 of the 115 constituents examined have concentrations above the method detection limit (MDL). Among these, only seven constituents are within 80% of the existing regulatory limits examined, and only antimony exceeded the CA maximum contaminant level (MCL). The presence of antimony was expected because it is a catalyst used in the synthesis to derive PET for plastic bottles, which is then recycled into both the PET face fiber and carpet underlayment. It is hypothesized that the levels of antimony and other leachate constituents would be less in actual field installations because water saturation times in field applications would most likely be much shorter than the soaking period used in the laboratory. Soil particles in the field may also adsorb contaminants, including heavy metals, and remove them from the water.

Leachate from powdered carpet backing was also analyzed, and the concentrations of the leachate constituents increased with decreasing pH. Few of the constituent concentrations exceeded the drinking water MCLs or aquatic life freshwater quality maximums. Direct discharge of the leachate might result in water quality impacts due to the concentrations of nitrogen compounds, magnesium and zinc, but those could be removed with soil mantel treatment.

Additionally, shredded RPC was analyzed by the Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) protocols, and results indicate that RPC is not considered a hazardous material.

Material property testing concluded that RPC is characterized as a lightweight material in comparison to soil and gravel, and has an average density of 1.19 g/cm^3, 1.01 g/cm^3, and 0.52 g/cm^3 for shredded RPC, RPC underlayment, and RPC face fiber (fluff), respectively. Shredded RPC also has high porosity
but lower hydraulic conductivities when compared to conventional construction materials like soil and gravel. Additionally, RPC generally has high compressibility and high surface area.

**Recommendations**

Based on laboratory results, background research of existing literature, and a review of industry-related products, GHD recommends conducting further research on the following civil engineering applications of RPC:

1. **Septic systems/infiltration**
   
   Septic system/infiltration applications using RPC are recommended for further research including an in-situ pilot study. RPC’s drainage properties combined with its high surface area may provide advantageous results for biomat formation in septic system and infiltration applications.

2. **Lightweight fill applications**
   
   Further research and in-situ pilot studies are recommended for lightweight fill applications using RPC. Because the density of RPC is lower than that of conventional fill materials like soil and gravel, RPC can potentially be a suitable lightweight fill material to be used in embankments or as retaining wall backfill material.

3. **Road surface reinforcement applications**
   
   Roadway surface reinforcement applications are also recommended for further analysis and pilot studies because the fiber content, porosity and density values of the RPC underlayment may be suitable as a pavement reinforcing layer.

4. **Erosion control and lightweight composites/concrete**
   
   Lightweight composites/concrete has already undergone extensive research, and erosion control with recycled carpet is already a manufactured product. Because these products have not gained widespread traction to-date, GHD recommends CARE to consider developing cost-benefit analyses and/or conducting future studies to determine the obstacles that are limiting the presence of recycled carpet erosion control products and lightweight recycled carpet concrete in the market.

**Next Steps**

Phase II will use the information from this report to conduct further research, and will focus on the implementation of pilot studies with the three identified civil engineering applications of RPC:

1. **Septic systems/infiltration**

2. **Lightweight fill applications**

3. **Road surface reinforcement applications**

Implementing RPC pilot studies for these civil engineering applications would allow scientists and engineers to better understand the in-situ performance of RPC, including water quality, rate of settlement, bacteriological interactions, filtration effectiveness, and tensile behavior in asphalt overlays.

Additionally, implementing pilot studies and collaborating with various industries and municipalities would allow CARE to further understand the benefits of RPC and initiate market development efforts to highlight the uses and benefits of RPC material in civil engineering applications. Through continued research and development, CARE and CalRecycle would be able to identify potential RPC uses, develop an outreach plan, and develop an incentive plan/grant program to promote the establishment and sustainability of new RPC markets.
List of Abbreviations

CA California
CalRecycle California Department of Resources Recycling and Recovery
Caltrans California Department of Transportation
CARE Carpet America Recovery Effort
CCSP California Carpet Stewardship Program
CU Concentration units
EPA Environmental Protection Agency
EPS Expanded polystyrene
ft foot or feet
gm gram
HCl hydrochloric acid
HSU Humboldt State University
kg kilogram
L liter
lb_{f} pound-force
lbs pounds
MCL Maximum contaminant level
MDL method detection limit
mg milligram
μg microgram
MSGP Multi-Sector general permit
N Nitrogen
No. Number
NTU Nephelometric Turbidity Units
PCC Post-Consumer Carpet
PET Polyethylene Terephthalate
PHG Public health goal
PP Polypropylene
psi pounds per square inch
RPC Recycled PET Carpet
SBR styrene-butadiene rubber
STLC solubility threshold limit concentrations
TCLP Toxic Characteristic Leaching Procedure
TDA tire derived aggregate
US United States
WET Waste Extraction Test
**Terminology**

1. *Civil engineering applications* – materials, means and methods related to the design, installation, and construction of built structures, which includes but are not limited to roads, buildings, systems for water supply and sewage treatment, and associated earthwork
2. *Compressibility* – the ability of a material to reduce in volume under applied pressure
3. *Density* – mass per unit volume
4. *Hydraulic conductivity* – the ease with which a fluid (i.e. water) can move through pore spaces
5. *Leachate* – water that has percolated through a material and leached out some of the constituents (i.e. chemicals, minerals)
6. *PET carpet* – carpet manufactured from recycled polyethylene terephthalate
7. *Porosity* – fraction of void spaces over the total volume
8. *RPC* – post-consumer/ recycled PET carpet; PET carpet that has served its useful life and recycled for use into other applications
9. *RPC fluff* – RPC face fibers that are produced through a shearing process to separate carpet face fibers from the backing
10. *RPC underlayment* – RPC padding installed under the carpet to provide carpet support and insulation. RPC underlayment is manufactured using RPC fluff through a process that includes washing, shredding, loosening, blending with additives to achieve uniform properties, needle stitching, and heat-treated for added strength.
11. *Shredded RPC* – mechanically shredded RPC, size ranging between 1 inch and 12 inches long, and includes carpet face fiber, adhesive layers and backing
12. *Water holding capacity* – the amount of water that is absorbed into a material
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Appendices

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1. Introduction

1.1 CARE’s California Carpet Stewardship Program

In 2008, discarded carpet comprised 3.2 percent by volume of waste disposed in California. To increase diversion and recycling of used carpets, California signed Assembly Bill (AB) 2398 in 2010 and established California’s Carpet Stewardship Law. AB 2398 designated Carpet America Recovery Effort (CARE) as the Carpet Stewardship Organization, with oversight by the California Department of Resources Recycling and Recovery (CalRecycle).

CARE’s California Carpet Stewardship Program (CCSP) provides grant funding to establish, increase, improve and enhance California-generated post-consumer carpet (PCC) collection, recycling, and utilization in recycled-content product manufacturing. In May 2016, the CCSP awarded approximately $2 million in grant funding for six capital improvements and three product testing projects that utilize California-generated PCC. The grant funding supports capital investment, infrastructure and/or equipment that will manufacture products utilizing California-generated PCC, as well as product testing and research activities, and/or feasibility studies on potential new uses of PCC. GHD was awarded funding to assess the feasibility of using recycled polyethylene terephthalate (PET) carpet in civil engineering applications.

1.2 PET Carpet and Potential Use in Civil Engineering Applications

According to the EPA, data from 1995-2000 indicated that the main polymers used for carpet face fiber are Nylon 6-6, Nylon 6, PET, and polypropylene (PP), with very small amounts of wool and bio-based fibers (EPA, 2015). Industry-wide, 60% of carpet by mass uses a nylon face fiber. To-date, CARE has successfully created a program to support the collection and reuse of nylon carpet, which has traditionally made up a majority of the recycled carpet waste stream. However, waste PET carpet has significantly increased in recent years. Although PET carpet constitutes only 10% of the market (Ucar and Wang 2008), it is not readily commercially recyclable like nylon. While the backing of the PET carpet is separated and manufactured into new products (similar to nylon-based carpet backing), an efficient and cost-effective use for the face fiber of recycled PET carpet (RPC) has not been developed. With PET’s growing presence in the carpet industry, this feasibility study focuses on PET carpet in order to identify a potential pathway to commercially recycle and reuse this material in civil engineering applications.

PET carpet fiber is manufactured from recycled soda and water bottles that were originally formed from pellets of PET resin. PET carpet fiber has gained traction in recent years because of the recyclability of PET and the relative abundance of post-consumer PET in the form of plastic bottles. PET carpet advocates report that because plastic beverage containers are made with top quality resins as required by the U.S. Food & Drug Administration, recycled PET is superior to lower grades of virgin synthetic fibers used in making other brands of polyester carpet yarns. Additionally, PET fibers are naturally stain-resistant, do not require the chemical treatments used on most nylon carpets, and they retain color and resist fading from exposure to the sun or harsh cleaning. PET fibers also have better abrasion resistance than other fibers, and therefore PET carpet is often used in lobbies and other high-traffic areas due to minimal need for maintenance. However, once the PET carpet has served its useful life, it is transferred to landfills. There are currently minimal cost-effective alternatives to reuse or recycle PET carpet.
GHD hypothesizes that the life cycle of PET resin can be extended through additional recycling and remanufacturing efforts. Specifically, instead of sending PET carpet to the landfill, PET carpet has the potential to be recycled at the end of its useful life, as "recycled PET carpet" (RPC), into a civil engineering product.

![Figure 1: Potential Life Cycle of PET Resin](image)

Because civil engineering projects (e.g. embankments, fill) typically require large amounts of earthwork and construction materials, recycling or remanufacturing PET carpet for use in civil engineering applications may be a potential and significant pathway to mitigate the amount of PET carpet that ends up in landfills. RPC could serve as a substitute for conventional construction materials. This project is the first step in developing a new market economy and creating a demand for post-consumer PET carpet in civil engineering applications as an alternative to landfill disposal.

### 1.3 Purpose and Scope of this Report

The purpose of this feasibility study is to determine civil engineering applications, if any, that may potentially utilize the beneficial properties of RPC. This feasibility study is the first phase (Phase I) to investigating and establishing a potential market for RPC. The background and research performed in this feasibility study consisted of 3 stages:

- **Preliminary investigation to identify possible uses of PET carpet.** Background research was performed, and a brainstorm session was held with multi-disciplinary team members to identify a preliminary list of civil engineering applications and corresponding material properties that may render RPC as a suitable construction material for civil engineering projects.

- **Laboratory testing of PET carpet through Humboldt State University (HSU).** PET carpet samples were tested under various conditions to determine the material performance and properties. Water quality samples were also taken to identify leachate water quality and potential environmental and regulatory issues.

- **Research on conventional construction materials.** Using laboratory results, RPC material characteristics were compared with properties of conventional construction materials in order to narrow down and identify civil engineering applications where RPC materials may bring benefits.

This feasibility study summarizes the preliminary investigations, laboratory analyses and research on conventional construction materials, and recommends civil engineering applications which may be suitable for future study.
2. Background

2.1 Carpet Composition

The carpet used in this feasibility study is of the most common type, referred to as tufted carpet. A generalized schematic of the carpet structure is shown in Figure 2. The carpet structure typically includes two polypropylene (PP) backing layers fused together using a calcium carbonate (CaCO\textsubscript{3})/styrene-butadiene rubber (SBR) thermoset adhesive (Wang et al. 2003; Wang, Wu, and Li 2000). The carpet face fiber, in this case PET, is tufted into the PP and adhesive layers. In addition to the materials used in the carpet itself, a padded underlayment is generally placed below the carpet.

![Figure 2: Layers of Carpet (Wang, Wu, and Li 2000)](image)

2.2 Properties and Synthesis of PET

PET is a partially aromatic thermoplastic polymer of the polyester family. Due to PET’s molecular composition, PET has a high melting temperature, good strength, light weight, good barrier properties and crease resistance. PET also exhibits high chemical and thermal resistance, making it popular for a variety of applications, which include food and beverage containers, fibers, textiles and films (Park and Kim 2014). Virgin PET typically has a density of 1.33 g/cm\textsuperscript{3}.

It is important to note that antimony trioxide (Sb\textsubscript{2}O\textsubscript{3}) is a common and important industrial catalyst added to synthesize PET. Catalysts are employed during the industrial PET syntheses in order to increase the production rate, reduce side reactions, and lower the energy cost of generating PET. Antimony trioxide has good catalytic activity and does not add color to the finished polymer (Duh 2002). Catalysts based on other metals have been reported to a lesser extent, but they include germanium, cobalt, titanium and aluminum (Park and Kim 2014; Thiele 2001).

For more information on the chemistry and properties of PET, including a description of the PET molecular structure, other catalysts added, and causes of PET degradation, a detailed summary is provided in Appendix A.

2.3 Manufacturing and Recycling of PET Carpet

PET carpet face fiber is made from recycled PET bottles by a mechanical recycling method called primary recycling (Park and Kim 2014). The process of recycling PET containers to carpet fiber is multi-stage. First, recycling facilities collect and ship the containers to a processing plant. Next, bottles are cleaned and separated from other plastics and their labels and lids. The bottles are then
ground into small chips and cleaned again. These chips are finally sent to the carpet manufacturer, which melt-extrudes the chips into carpet fibers.

Impurities are introduced to PET bottle chips during the recycling process (Andrzej Pawlak et al. 2000). Impurities can result from any leftover impurities from the bottle manufacturer; incomplete separation of PET from other plastics; contamination from bottle labels and adhesives; and substances the bottle contacted during its lifespan that were not removed during washing. Such impurities are known to increase degradation rates during reprocessing (Awaja and Pavel 2005; Park and Kim 2014). Color and dyes are also oftentimes added to PET carpet during the manufacturing process to address aesthetics and marketability objectives. These impurities should be considered as potentially present in finished carpet fiber.

Because RPC have undergone further processing, the properties of RPC will differ from virgin PET. Additionally, impurities and contaminants from environmental exposures can also be adsorbed to the surface of the face fiber during the carpet life span. Laboratory testing of PET carpet properties and quantification of leachate constituents is critical in order to determine potential civil engineering applications for recycled PET carpet.

The forms of RPC considered for this feasibility study include shredded carpet, carpet face fiber, carpet underlayment, and to a limited extent, calcium carbonate backing. Shredded carpet is created by sending the RPC through a mechanical shredder; the purpose is to generate smaller pieces of the carpet without extracting any particular component. Carpet face fiber is produced by feeding the carpet through a machine that shears the carpet face fibers from the backing, in which the backing is subsequently transferred to a separate recycling facility for further processing. In order to manufacture the carpet underlayment, the carpets are washed, shredded, loosened, blended to achieve uniform properties, needle-stitched together, and heat-treated for added strength. The calcium carbonate backing assessed in this study is a powdered material that was developed as a result of the carpet recycling processes described above.

2.4 Brainstorming Possible Uses of RPC in Civil Engineering Applications

A brainstorming session was held at the GHD Santa Rosa, CA location to generate ideas on possible uses of RPC in civil engineering applications. Participants represented a number of different disciplines, including civil engineering, geotechnical engineering, environmental and regulatory compliance, chemistry, and geology. Based on a discussion of RPC, its uses, and the carpet form (i.e. size and configuration), the team developed a list of potential applications and highlighted the material properties required in order to evaluate the feasibility of using it as a substitute for existing materials.

Civil engineering applications identified include: water control purposes (i.e. drainage, erosion control), fill material, roadway reinforcement layer, and lightweight composites/concrete. These applications were chosen for this feasibility study based on a preliminary understanding of the carpet material size and texture, considerations on constructability, and from examples of recycled products that are currently used in the industry; the applicability of RPC to these civil engineering applications would need to be further verified through extensive laboratory testing, pilot projects, and field studies. Potential applications of RPC and notes from the brainstorming session are provided in Appendix B.
3. Laboratory Testing of RPC Properties

In order to understand how RPC might perform in civil engineering applications involving water control, fill material, roadway reinforcement layer, and lightweight concrete, it is critical to first understand the density, compressibility, hydraulic conductivity, and porosity values. Humboldt State University (HSU) was retained by GHD to perform the laboratory testing of the PET material properties, and this effort was led by Dr. Brad Finney, who is a professor of Environmental Resources Engineering at HSU.

In addition to the physical properties, evaluating potential reuse pathways for post-consumer PET carpet also requires understanding the potential water quality impacts of the leachate should the material come into contact with water. In this study, some physical properties and leachate water quality characteristics were determined for shredded RPC, RPC face fiber or “fluff”, and RPC carpet underlayment. Only a leachate analysis was performed for the powdered carpet backing. Initial testing was performed utilizing existing testing equipment at the HSU facility. Due to the physical constraints of some of the materials, not all physical property tests were performed on every type of RPC material.

Figure 3: Carpet samples used for mechanical and water quality tests. Clockwise from upper left: a) Shredded carpet pieces; b) Bale of compressed face fiber; c) Expanded fluff as tested; d) Carpet underlayment; e) Powdered carpet backing (center inset)
Shredded PET carpet used for this study was provided by West Coast Rubber Recycling in Hollister, CA. The PET carpet underlayment used for this study is known as Reliance Carpet Cushion, which is manufactured by Los Angeles Fiber. Los Angeles Fiber also provided the PET carpet fluff.

The shredded carpet used for the laboratory analysis showed little sign of wear and appeared to be relatively clean. To simulate sizes that would be easily managed in civil engineering applications, the material was hand sorted, retaining pieces that were between 1 inch and 12 inches long (Figure 3a). The carpet face fiber, which consists of carpet fibers without the backing, was delivered in a 700 pound compressed bale (Figure 3b). The material was separated out of the bale and hand “fluffed” to produce a product closer to uncompressed carpet fibers (Figure 3c). The underlayment was delivered in a roll and cut into smaller pieces for easier handling (Figure 3d). Five pounds of recycled powdered carpet backing was provided for testing. The coarse, powdery carpet backing material (Figure 3e), which consists of binders and fillers, was collected as PET fibers were recovered from recycled carpet.

The laboratory tests for RPC materials were performed by HSU, and the water quality tests were subcontracted to Alpha Analytical Laboratories, Inc. A summary of the experimental procedures and the results of the experiments are presented in the following sections. HSU’s report titled, “Physical Properties and Leachate Water Quality of PET Carpet,” dated October 2016 is provided in Appendix C.

As part of the laboratory analysis, RPC material properties were compared with the material properties of tire-derived aggregate (TDA), which is a lightweight material generated from used scrap tires and is currently used in civil engineering applications. The development and applications of TDA stemmed from similar initiatives as the CCSP: to divert the amount of waste that end up in landfills, CalRecycle has performed extensive materials testing and research since the 1980s to identify and promote individual market areas for use of scrap tires. Due to TDA’s beneficial material properties, TDA has now been installed in a number of civil engineering applications, including lightweight embankment fill, landslide repair/slope stabilization, landfill gas and leachate collection trenches, retaining wall backfill, stormwater treatment trenches, and vibration mitigation for light-rail. The TDA program has been a successful program and has set precedence for the testing and evaluation of RPC in civil engineering applications. Because TDA is also a recycled material used in civil engineering applications, a direct comparison between TDA material properties and the laboratory results of RPC would provide a general overview of the performance of RPC. HSU also performed the laboratory testing of TDA. In addition to TDA, RPC material properties were compared with other conventional civil engineering materials. This comparison is summarized in Chapter 4.

3.1 Physical Properties of RPC

Physical properties, including density, porosity, water holding capacity, compressibility, and hydraulic conductivity were determined for the carpet materials under a variety of loading conditions, as discussed in the following sections.

3.1.1 Density and Water Holding Capacity

The density of the PET carpet was determined using the water displacement technique. The shredded carpet and carpet underlayment density was determined for three carpet samples (each approximately 77 gm) and four underlayment samples (each approximately 20 gm). Three different density determinations were made for a single, 37 kg carpet fluff sample.
The average observed density of the shredded carpet and underlayment was 1.19 g/cm$^3$ and 1.01 g/cm$^3$ respectively. The density was expected to be higher for the carpet compared to the underlayment since the carpet has a relatively heavy calcium carbonate backing. The density of the carpet fluff was determined to be 0.52 g/cm$^3$, about half that of the carpet pieces and underlayment.

The higher density of the underlayment compared to the fluff may be due to the heat treatment the fluff receives which fuses together the fibers in the top and bottom surface of the material. Other differences in the fluff and underlayment samples include mass of the material tested and the preparation the sample received prior to testing. The fluff mass tested was nearly 100 times larger than the underlayment and the fluff was not oven dried prior to testing. However, neither of these conditions is believed to be responsible for the differences between the measured fluff and underlayment density.

The water holding capacity of the carpet and carpet underlayment was determined by soaking the oven-dried material in water for 24-hours, then allowing the material to gravity drain. The difference in weight between the pre-soak and post-gravity draining was recorded and the water holding capacity is provided in Table 1. Carpet fluff was not tested for water absorption because it is dependent on compaction loads, which can vary depending on the manufacturer, supplier, and installation process.

### Table 1: Water Holding Capacity and Density of Recycled Carpet Products

<table>
<thead>
<tr>
<th>Material</th>
<th>Water absorption (% increase in mass)</th>
<th>Average measured density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shredded carpet</td>
<td>206</td>
<td>1.19</td>
</tr>
<tr>
<td>Carpet fluff</td>
<td>Not tested</td>
<td>0.52</td>
</tr>
<tr>
<td>Carpet underlayment</td>
<td>131</td>
<td>1.01</td>
</tr>
</tbody>
</table>

#### 3.1.2 Compressibility, porosity and hydraulic conductivity

A large diameter compression apparatus that was designed and fabricated specifically for testing recycled materials under loads equivalent to 100 feet of soil fill (115 psi) was used to determine the compressibility, porosity, and hydraulic conductivity of shredded carpet and carpet fluff. RPC underlayment was not tested due to physical constraints. The compression cylinder has a 29.7 inch inside diameter, and can hold a 30-inch deep layer of sample. The vertical loading force applied to the sample is measured by four load cells (pressure transducers), each with a 30,000 lb$_f$ capacity. The load cells rest on the solid bottom of the cylinder, separated from the carpet material by a perforated steel plate. A steel piston, driven by manually operated hydraulic bottle jacks, provides the loading force on the sample.

The entire apparatus rests on a 4-foot square digital scale with a 3,000-lb$_f$ capacity and an accuracy of ±1.0 lb$_f$. Water enters and leaves the cylinder via a fitting near the base of the unit. Water can also be added to the top of the cylinder and a constant head can be maintained by adjusting the inflow rate to exceed the outflow at the bottom, resulting in an overflow along the top lip of the cylinder.

The compressibility, porosity, and hydraulic conductivity of shredded carpet and carpet fluff were determined under loads ranging from 230 to 39,505 lbs. (0.33 to 57 psi). In addition, once the maximum load on the sample was reached, the load was released and the change in the compression of the material was noted over a 24-hour period. Four different experiments were conducted with the compression apparatus, with the first three having a shredded carpet sample.
and the fourth having a carpet fluff sample. The three experiments conducted with shredded carpet differed in their pre-loading (vertical load applied during the fill).

The three carpet samples exhibited similar compressibility (strain) when loaded. In Experiment 1, the carpet was loosely filled in the test chamber and subsequently compressed at very small loads. In this experiment, the carpet sample compressed by more than 50% under a load of 1 psi and approximately 70% at a load of 10 psi. The compression apparatus is unable to test a sample beyond approximately 70% compaction, therefore Experiment 1 ended with a maximum load of 11.5 psi.

The stress-strain relationship of the preloaded samples in Experiments 2 and 3 were very similar, and the samples both exhibited less strain than the Experiment 1 sample at similar loading. The difference in the preloading (3.5 psi vs. 6.2 psi) appears to be responsible for the small difference in strain between the Experiment 2 and 3 shredded carpet samples. The response of the carpet fluff to loading follows the same trend as the carpet, but fluff has approximately 10% higher percent compression at comparable vertical loading rates than the carpet in Experiment 3 (Figure 4). Up to the maximum load tested (68 psi), carpet and fluff are considerably more compressible than TDA. For example, at a vertical load of 60 psi, the vertical strain on the carpet is approximately 70%, while the strain on the TDA as reported by Finney et al. (2013) is less than 60%.

The relationship between the load applied and the porosity of the shredded carpet and fluff is similar to the behavior observed for the compressibility of the materials (Figure 5). At loads less than 5 psi, the porosity of the carpet products varied between 56% and 87%. With increasing load, the porosity rapidly decreased. At a 40-psi load, the porosity of the shredded carpet with a 3.5-psi and 6.2 psi preload was approximately 30% and 42% respectively. The porosity of the fluff was lower than the shredded carpet at equivalent loads. For example, at 31 psi, the 6.2 psi preloaded fluff had a porosity of 26%, while at the same load the carpet had a porosity of 45%. The behavior of the shredded carpet porosity to loading is remarkably similar to that of TDA. While Finney et al. (2013) did not determine the porosity of TDA at the intermediate loads that were applied to the

![Figure 4: Vertical stress in RPC and TDA resulting from applied load](image-url)
carpet, the interpolated response curve of TDA porosity to load applied appears to be between the curves for the two preloaded shredded carpet samples (Figure 5).

**Figure 5:** Change in the porosity in RPC and TDA from applied load

**Figure 6:** Change in hydraulic conductivity of RPC and TDA from applied load
The change in hydraulic conductivity to changes in loads applied was very similar for shredded carpet and fluff at all preloading conditions (Figure 6). Considering all of the computed values from the four experiments together, the hydraulic conductivity ranged from 265 ft/day at 4 psi to 7 ft/day at 68 psi. Ignoring the points at loads below 1 psi, the change in the log value of the hydraulic conductivity was linear with the change in the log of the load applied. In general, the hydraulic conductivity for the carpet products was much lower than previously reported for TDA. For example, Finney et al. (2013) reported a hydraulic conductivity of 307 ft/day for TDA at 44 psi while in Experiment 3, a hydraulic conductivity of 16 ft/day was determined for shredded carpet at 40 psi. Finney et al. (2013) also reported that the hydraulic conductivity of TDA appeared to change with the applied hydraulic head, an unusual phenomenon not observed in the carpet material in this study.

3.2 Leachate Analysis of Recycled PET Carpet

Several tests were performed to analyze the leachate constituents of RPC. To start, GHD provided HSU a list of possible contaminants that could be introduced to water, air or soil as a result of environmental exposure. The preliminary constituents list, included in Appendix D, was developed by reviewing existing research literature, and after comparison to regulatory standards. These chemicals may be present in or on the surface of recycled PET carpet fiber due to the chemistry and manufacturing processes, and therefore both hazardous material assessments and water quality analyses were performed.

3.2.1 Hazardous Material Assessment

A Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) analysis were performed on a shredded carpet sample, which contained carpet face fiber and underlayment, and is assumed to be a representative sample for the TCLP and WET analyses. Both the TCLP and WET methods are used as part of a protocol to determine whether a material is a hazardous waste. The US EPA developed the TCLP method, and the WET method was originally developed by the State of California. Both methods involve an acid leachate extraction process to simulate the situation in a setting such as a landfill. The methods differ from one another by the acid used in the extraction, the length of time the material is subject to the acid, and by the water quality constituents examined.

Only a few of constituents were determined to have concentrations above the method detection limit (MDL). If the concentrations of any of the constituents tested exceed the solubility threshold limit concentrations (STLC), the tested material is classified as a hazardous waste. The concentrations of detected constituents in the shredded carpet WET and TCLP analysis were at least two orders of magnitude lower than the STLC. Therefore based on this criterion, the carpet would not be considered a hazardous waste. Table 2 summarizes these results.

Table 2: Constituents detected in WET and TCLP analysis compared to the STLCs

<table>
<thead>
<tr>
<th>Test</th>
<th>Constituent</th>
<th>Result (mg/L)</th>
<th>STLC(a) (mg/L)</th>
<th>Above STLC?</th>
</tr>
</thead>
<tbody>
<tr>
<td>WET</td>
<td>Antimony</td>
<td>0.023</td>
<td>15</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Barium</td>
<td>0.45</td>
<td>100</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Chromium</td>
<td>0.066</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Cobalt</td>
<td>0.016</td>
<td>80</td>
<td>No</td>
</tr>
<tr>
<td>Test</td>
<td>Constituent</td>
<td>Result (mg/L)</td>
<td>STLC&lt;sup&gt;(a)&lt;/sup&gt; (mg/L)</td>
<td>Above STLC?</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>---------------</td>
<td>-----------------------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td>0.14</td>
<td>25</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>0.46</td>
<td>180</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>0.042</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Molybdenum</td>
<td>0.13</td>
<td>350</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Nickel</td>
<td>0.15</td>
<td>20</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Thallium</td>
<td>0.04</td>
<td>7</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td>3</td>
<td>250</td>
<td>No</td>
</tr>
<tr>
<td>TCLP</td>
<td>Barium</td>
<td>0.051</td>
<td>100</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Chromium</td>
<td>0.022</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>0.0092</td>
<td>5</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes:
(a) STLC values are calculated on the concentrations of the elements, not the compounds.

### 3.2.2 Water Quality for RPC Face Fiber, Shredded Carpet, and Underlayment

In addition to hazardous material analysis, the carpet leachate water quality was studied as a function of carpet sample type, water exposure duration, and whether carpet was pre-rinsed. Except for the powdered carpet backing, all samples were soaked in water for one month except for a single shredded carpet sample type. The powdered carpet backing material was treated a bit differently than the other recycled carpet products, and is discussed in Section 3.2.3.

Three of the five leachate sample types included all carpet layers – the face fiber, shredded carpet and underlayment, and differed only in their soak time and whether prior rinsing was used. The remaining two samples tested individual carpet layers – either the underlayment or face fiber. No rinsing experiment was done for the underlayment or face fiber sample types. Table 3 summarizes sample information. Jars containing only distilled water were also sampled to serve as blanks.

**Table 3: Sample types analyzed for leachate water quality**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Soak Duration</th>
<th>No. of Samples</th>
<th>Assumed Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpet – 1</td>
<td>1 month</td>
<td>3</td>
<td>Shredded carpet (Face fiber, backing, and underlayment combined)</td>
</tr>
<tr>
<td>Carpet – 2</td>
<td>2 months</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Rinsed carpet</td>
<td>1 month after 2 month soak and rinse</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Underlayment</td>
<td>1 month</td>
<td>2</td>
<td>Underlayment</td>
</tr>
<tr>
<td>Face fiber</td>
<td>1 month</td>
<td>2</td>
<td>Face fiber</td>
</tr>
</tbody>
</table>

Soaking was performed by placing samples in large glass jars, and leachate was sampled directly from the container following the specified soak duration. Each leachate sample was then analyzed for a wide range of water quality constituents, ranging from common organic and inorganic compounds to a wide assortment of volatile and semi-volatile compounds. A complete list of all...
water quality constituents analyzed and the associated detection limits is provided in HSU’s report in Appendix C.

The concentrations of the constituents in the leachate are of interest as this might be considered a “worst case” scenario of a situation where the water saturating a carpet material fill for a month or longer is suddenly released into a receiving environment. The magnitude of the concentration compared to regulatory limits is shown in Table 8, with bolded results indicating exceedance of any regulatory value. This provides a way to characterize the potential for a constituent leaching from RPC based materials to be a water quality concern. The regulatory standards used for comparison to the constituent concentrations in carpet product leachate serve only as a point of reference for these worst-case scenarios. The selected standards apply primarily to drinking water and are not necessarily representative of appropriate regulatory frameworks for typical RPC applications.

*It is important to note that the minimum soaking/saturation duration used in this laboratory study was 1 month. Scenarios where RPC material would be used in civil engineering applications with much shorter soak periods could result in much lower concentrations, and these applications should be investigated further to determine leachate water quality.*

Table 4 shows the full list of constituents targeted for water quality analysis, with bolded items indicating results above method detection limits (MDLs). Only 22 of the 115 constituents examined were determined to have concentrations above the MDL. The detected constituents were primarily metals, with none of the volatile or semi-volatile compounds found above the MDL.

*Table 4: Water quality constituents analyzed for RPC leachate (bolded items detected above MDLs)*

<table>
<thead>
<tr>
<th>Method</th>
<th>Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals by EPA 200 Series Methods</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>Lithium</td>
</tr>
<tr>
<td>Antimony</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Manganese</td>
</tr>
<tr>
<td>Barium</td>
<td>Mercury</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Nickel</td>
</tr>
<tr>
<td>Chromium</td>
<td>Selenium</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Silver</td>
</tr>
<tr>
<td>Copper</td>
<td>Sodium</td>
</tr>
<tr>
<td>Iron</td>
<td>Sulfur</td>
</tr>
<tr>
<td>Lead</td>
<td>Zinc</td>
</tr>
<tr>
<td>Conventional Chemistry Parameters by APHA/EPA methods</td>
<td></td>
</tr>
<tr>
<td>Ammonia as N (SM4500NH3C)</td>
<td>Odor (EPA 140.1)</td>
</tr>
<tr>
<td>Color (SM2120B)</td>
<td>Turbidity (SM2130B)</td>
</tr>
<tr>
<td>Chloride</td>
<td>Orthophosphate</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>Chloroethane</td>
</tr>
<tr>
<td>VOCs by EPA Method 8260B</td>
<td>1,1,1,2-Tetrachloroethane</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>Chloroform</td>
</tr>
<tr>
<td>Method</td>
<td>Constituents</td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>Chloromethane</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>cis-1,2-Dichloroethene</td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
<td>cis-1,3-Dichloropropene</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>Dibromochloromethane</td>
</tr>
<tr>
<td>1,1-Dichloropropene</td>
<td>Dibromomethane</td>
</tr>
<tr>
<td>1,2,3-Trichlorobenzene</td>
<td>Dichlorodifluoromethane</td>
</tr>
<tr>
<td>1,2,3-Trichloropropene</td>
<td>Ethylbenzene</td>
</tr>
<tr>
<td>1,2,4-Trichlorobenzene</td>
<td>Hexachlorobutadiene</td>
</tr>
<tr>
<td>1,2,4-Trimethylbenzene</td>
<td>Isopropylbenzene</td>
</tr>
<tr>
<td>1,2-Dibromo-3-chloropropane</td>
<td>m,p-Xylene</td>
</tr>
<tr>
<td>1,2-Dibromoethane (EDB)</td>
<td>Methyl ethyl ketone</td>
</tr>
<tr>
<td>1,2-Dichlorobenzene</td>
<td>Methyl isobutyl ketone</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>Methyl tert-butyl ether</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
<td>Methylene chloride</td>
</tr>
<tr>
<td>1,3,5-Trimethylbenzene</td>
<td>Naphthalene</td>
</tr>
<tr>
<td>1,3-Dichlorobenzene</td>
<td>n-Butylbenzene</td>
</tr>
<tr>
<td>1,3-Dichloropropane</td>
<td>n-Propylbenzene</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>o-Xylene</td>
</tr>
<tr>
<td>2,2-Dichloropropane</td>
<td>p-Isopropyltoluene</td>
</tr>
<tr>
<td>2-Chlorotoluene</td>
<td>sec-Butylbenzene</td>
</tr>
<tr>
<td>2-Hexanone</td>
<td>Styrene</td>
</tr>
<tr>
<td>4-Chlorotoluene</td>
<td>tert-Butylbenzene</td>
</tr>
<tr>
<td>Acetone</td>
<td>Tetrachloroethene</td>
</tr>
<tr>
<td>Benzene</td>
<td>Toluene</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>trans-1,2-Dichloroethene</td>
</tr>
<tr>
<td>Bromochloromethane</td>
<td>trans-1,3-Dichloropropene</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>Trichloroethene</td>
</tr>
<tr>
<td>Bromoform</td>
<td>Trichlorofluoromethane</td>
</tr>
<tr>
<td>Bromomethane</td>
<td>Trichlorotrifluoroethane</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>Vinyl acetate</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Vinyl chloride</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>Xylenes (total)</td>
</tr>
<tr>
<td>Semi-volatile Organic Compounds by EPA Methods 625 SIM</td>
<td>2-Methylnaphthalene Di(2-ethylhexyl)adipate</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>Di(2-ethylhexyl)phthalate</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>Dibenz (a,h) anthracene</td>
</tr>
<tr>
<td>Anthracene</td>
<td>Di-n-butyl phthalate</td>
</tr>
<tr>
<td>Benzo (a) anthracene</td>
<td>Fluoranthene</td>
</tr>
<tr>
<td>Benzo (a) pyrene</td>
<td>Fluorene</td>
</tr>
<tr>
<td>Benzo (b) fluoranthene</td>
<td>Indeno (1,2,3-cd) pyrene</td>
</tr>
</tbody>
</table>
Effect of Rinsing

A rinsing experiment was conducted to determine whether water quality could be improved by an initial “flush” of water. In this experiment, shredded carpet was soaked for two months, and then the leachate gravity drained from the jar. The jar was then refilled with distilled water and allowed to soak again for one month prior to sampling.

Results from the rinsed carpet show that concentrations for all constituents were reduced after the two-month soak. As shown in Table 5, this rinsing procedure reduced concentrations of the constituents by 22 to 99% (median of 69%). This result could indicate that the surface-bound constituents are removed via the rinsing procedure, or that the carpet material is continually leaching components over time but the leach rates are decreasing. Either way, the effect of rinsing could be an option explored for applications where water quality concerns may arise.

Note that there were several constituents that were not detected (ND) during the laboratory tests, denoted with “(a)” in Table 5. In order to estimate the percent reduction between the 2-month soaked carpet and the rinsed carpet, half the MDL for the corresponding constituent was assumed as the concentration for the rinsed carpet. This assumption was based on the EPA’s Technical Guidance Manual on “Chemical Concentration Data Near the Detection Limit,” which assumes that the average value of non-detects could be as high as half the detection limit (Roy, 1991). If non-detected values were handled as detection limits, then the result would always produce a mean concentration that is biased high. If non-detects are reported as zero, then all undetected chemicals are assumed absent. Given that there were limited samples, assuming half the MDL would provide the least biased estimate of assessing the percent concentration reduction after rinsing; however, the value does not indicate the actual concentration.

Table 5: Effect of rinsing shredded carpet sample

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Carpet – 2 month soak concentration</th>
<th>Rinsed carpet concentration</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>0.11</td>
<td>0.073</td>
<td>34</td>
</tr>
<tr>
<td>Antimony</td>
<td>mg/L</td>
<td>0.0088</td>
<td>0.003</td>
<td>66</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0.0111</td>
<td>0.0087</td>
<td>22</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.0011</td>
<td>0.00015</td>
<td>86</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.015</td>
<td>0.002</td>
<td>87</td>
</tr>
<tr>
<td>Cobalt</td>
<td>mg/L</td>
<td>0.003</td>
<td>0.001</td>
<td>67</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.0324</td>
<td>0.004</td>
<td>88</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>0.524</td>
<td>0.24</td>
<td>54</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>4.7</td>
<td>1.9</td>
<td>60</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>0.0368</td>
<td>0.018</td>
<td>51</td>
</tr>
<tr>
<td>Mercury</td>
<td>μg/L</td>
<td>0.057</td>
<td>0.005</td>
<td>91</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.0043</td>
<td>73</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>138.6</td>
<td>60</td>
<td>57</td>
</tr>
<tr>
<td>Constituent</td>
<td>Units</td>
<td>Carpet – 2 month soak concentration</td>
<td>Rinsed carpet concentration</td>
<td>% Reduction</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>------------------------------------</td>
<td>-----------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Sulfur</td>
<td>mg/L</td>
<td>49.5</td>
<td>0.015</td>
<td>-</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.46</td>
<td>0.015</td>
<td>97</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>29</td>
<td>0.28</td>
<td>99</td>
</tr>
<tr>
<td>Color</td>
<td>CU</td>
<td>83</td>
<td>17</td>
<td>80</td>
</tr>
<tr>
<td>Odor</td>
<td>TON</td>
<td>&gt;8000</td>
<td>&gt;8000</td>
<td>-</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>36.54</td>
<td>0.3</td>
<td>99</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>17.92</td>
<td>7.3</td>
<td>59</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>mg/L</td>
<td>0.081</td>
<td>0.044</td>
<td>46</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>mg/L</td>
<td>9.95</td>
<td>3.1</td>
<td>69</td>
</tr>
</tbody>
</table>

**Range** 22 - 99

**Median** 68

*Note:*

(a) Constituent was not detected during analysis. Values listed are one-half of the MDL, and were assumed for the purposes of calculating a percent reduction.

**Unit Mass Loading**

Results from the leachate experiment can also be presented as a per unit mass loading, with units of mg of constituent per kg of the carpet material. Since the density of carpet, underlayment, and fluff are different from one another, and the exact amount of material added to each glass jar differed, the unit mass loading rate provides a normalized comparison of the relative rate at which the materials leach compounds into water compared to one another.

There is considerable variability in the per-unit loading of the constituents across carpet, fluff and underlayment (Table 6). There does not appear to be a trend where one type of product consistently has a higher load of a constituent per unit mass of carpet product than the others. Comparing the carpet that soaked one month versus two months shows numerous cases were the shorter soak period resulted in a greater mass of the constituent being found in the leachate, a counter intuitive outcome.

**Table 6: Unit mass loading of constituents for all leachate carpet samples**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units (a)</th>
<th>Carpet 1 mo</th>
<th>Carpet 2 mo</th>
<th>Rinsed carpet</th>
<th>Underlayment</th>
<th>Face Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/kg</td>
<td>1.00</td>
<td>-</td>
<td>0.611</td>
<td>1.44</td>
<td>5.31</td>
</tr>
<tr>
<td>Antimony</td>
<td>mg/kg</td>
<td>0.087</td>
<td>0.0747</td>
<td>-</td>
<td>4.93</td>
<td>0.710</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/kg</td>
<td>0.113</td>
<td>0.093</td>
<td>0.073</td>
<td>0.336</td>
<td>0.325</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/kg</td>
<td>-</td>
<td>0.010</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/kg</td>
<td>-</td>
<td>0.137</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cobalt</td>
<td>mg/kg</td>
<td>0.032</td>
<td>0.025</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>-</td>
<td>0.53</td>
<td>0.033</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>4.44</td>
<td>5.00</td>
<td>2.008</td>
<td>3.21</td>
<td>2.62</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/kg</td>
<td>48.9</td>
<td>38.7</td>
<td>15.9</td>
<td>35.3</td>
<td>51.1</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/kg</td>
<td>0.326</td>
<td>0.451</td>
<td>0.151</td>
<td>0.199</td>
<td>0.324</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/kg</td>
<td>-</td>
<td>0.0009</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/kg</td>
<td>-</td>
<td>0.146</td>
<td>0.036</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Constituent</td>
<td>Units(^{(a)})</td>
<td>Carpet 1 mo</td>
<td>Carpet 2 mo</td>
<td>Rinsed carpet</td>
<td>Underlay-ment</td>
<td>Face Fiber</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------------</td>
<td>---------------</td>
<td>------------</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/kg</td>
<td>725</td>
<td>2467</td>
<td>502</td>
<td>740</td>
<td>735</td>
</tr>
<tr>
<td>Sulfur</td>
<td>mg/kg</td>
<td>181</td>
<td>783</td>
<td></td>
<td>233</td>
<td>295</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>-</td>
<td>4.20</td>
<td>0.126</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/kg</td>
<td>-</td>
<td>265</td>
<td>2.343</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Color</td>
<td>CU</td>
<td>70</td>
<td>91.7</td>
<td>-</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td>Odor</td>
<td>TON</td>
<td>&gt;8000</td>
<td>&gt;8000</td>
<td>-</td>
<td>4.45</td>
<td>21.1</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>39.5</td>
<td>46.73</td>
<td>-</td>
<td>0.43</td>
<td>0.61</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/kg</td>
<td>127</td>
<td>295</td>
<td>61.1</td>
<td>220</td>
<td>286</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>mg/kg</td>
<td>-</td>
<td>0.896</td>
<td>0.368</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>mg/kg</td>
<td>-</td>
<td>164</td>
<td>25.9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note:
(a) mg/kg = mg constituent per kilogram carpet sample
- = Not Tested

Regulatory Context

The magnitude of the concentration compared to regulatory frameworks (Table 7) and regulatory standards (Table 8) provides a way to characterize the potential for a constituent leaching from PET carpet based materials to be a water quality concern.

The regulatory standards used for comparison to the constituent concentrations in carpet product leachate serve only as a point of reference for these worst-case scenarios. The selected standards apply to drinking water and protection of freshwater aquatic systems; this list is not necessarily representative of appropriate regulatory frameworks for typical recycled carpet product applications, and is provided for illustrative purposes only.

Table 7: Regulatory frameworks used to assess leachate water quality

<table>
<thead>
<tr>
<th>Regulatory Framework</th>
<th>Agency</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Maximum Contaminant Level (CA MCL)</td>
<td>California Department of Public Health</td>
<td>Drinking water</td>
</tr>
<tr>
<td>Maximum Contaminant Level (MCL)</td>
<td>US EPA</td>
<td>Drinking water</td>
</tr>
<tr>
<td>Public Health Goal (PHG)</td>
<td>CA Office of Environmental Health Hazard Assessment</td>
<td>Drinking water</td>
</tr>
<tr>
<td>Aquatic Life Freshwater Quality Maxima</td>
<td>US EPA</td>
<td>Health of freshwater organisms</td>
</tr>
<tr>
<td>Multi-Sector General Permit Benchmark (MSGP Benchmark)</td>
<td>US EPA</td>
<td>Stormwater discharges associated with industrial activity</td>
</tr>
</tbody>
</table>

Of the 22 constituents detected above MDL (Table 4), 13 are regulated by one of the frameworks listed above. Of the 13 constituents, only seven (7) were detected in leachate samples within 80% of the regulated value (Table 8). Of these seven constituents, only antimony, a heavy metal, exceeds the CA MCL limit, while the remaining six (6) exceed or approach values for freshwater aquatic protection, PHG or MSGP. These results are presented graphically in Figure 7.
# Table 8: RPC Leachate Results Compared to Water Quality Regulatory Limits

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Samples</th>
<th>Regulatory Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Carpet 1 month</td>
<td>Carpet 2 month</td>
</tr>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>0.11</td>
<td>0.073</td>
</tr>
<tr>
<td>Antimony</td>
<td>mg/L</td>
<td>0.0096</td>
<td>0.0081</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0.0125</td>
<td>0.0102</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.011</td>
<td>0.004</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.015</td>
<td>0.004</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.058</td>
<td>0.004</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>5.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>0.0016</td>
<td>0.0043</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.46</td>
<td>0.015</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>29</td>
<td>0.28</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>mg/L</td>
<td>0.098</td>
<td>0.044</td>
</tr>
</tbody>
</table>

Notes:
- (a) Only the five frameworks from Table 7 were considered for this comparison. Frameworks included if any sample was at or above 80% of the regulatory limit shown in parentheses
- (b) Total recoverable
Figure 7: Constituents Exceeding or within 80% of the Regulated Limit

Abbreviations
C1 = one-month soak PET carpet
C2 = two-month soak PET carpet
CR = one month soak of rinsed carpet
F = PET carpet face fiber
U = PET Underlayment
ND = Not Detected
Possible Constituent Origins and Recommendations

The carpet samples received were seemingly clean, and it is assumed, unused. Therefore the constituents detected are most likely the direct result of the various upstream production processes, including PET bottle fabrication; bottle recycling process; carpet yarn fabrication; carpet fabrication; or the carpet recycling process. It is unlikely that constituents would have been introduced to the current samples as a result of normal use in flooring. However as future samples will contain post-consumer carpet, carpet flooring additives should not be ruled out for future studies; these could include, among others: insecticides/mitocides/rodenticides, cleaners and dirt and filth introduced by pets and pedestrians.

The presence of antimony above the CA MCL could be due to its use as a commercial catalyst in the synthesis of PET used to make drinking water bottles (Duh 2002), which ultimately become carpet face fiber and carpet underlayment. Trace quantities of the antimony used in PET synthesis are trapped in the bottle-grade plastic film, but can be released over time, especially during the harsh conditions of repeated recycling steps. It has been estimated that antimony concentrations in PET water bottles can exceed 200 mg antimony per kilogram PET (Westerhoff et al. 2008), though it is unlikely that all of this mass would be released.

It is important to note that this laboratory investigation evaluated PET carpet that filled a container and submerged in water for a period of 1 to 2 months. In actual field installations, it is not anticipated that the material will experience such a high density in standing water for such a long duration. Additionally, the surfaces of soil particles often are chemically reactive and provide multiple means by which contaminants in water, including heavy metals, can be adsorbed by soil particles and effectively removed from the water. Therefore, the water quality results, especially in the case of antimony, may be the worst-case scenario. Field installations are highly recommended to determine whether the levels of antimony continue to exceed regulatory limits.

3.2.3 Water Quality for Powdered Carpet Backing

The powdered carpet backing material was analyzed differently than the other recycled carpet products. While the material was reported by the supplier to be primarily calcium carbonate and latex adhesives, the actual composition of was unknown. Therefore, the dry mass composition of the material was determined for each of the constituents listed in Table 9.

Table 9 shows the full list of constituents targeted for water quality analysis, with bolded items indicating results above the MDLs. Of the 195 constituents examined, 43 constituents were determined to have concentrations above the MDL.

Table 9: Composition of Powdered Carpet Backing
(bolded items detected above MDLs)

<table>
<thead>
<tr>
<th>Method</th>
<th>Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals by EPA 200 Series Methods</td>
<td>Aluminum</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
</tr>
<tr>
<td></td>
<td>Antimony</td>
</tr>
<tr>
<td></td>
<td>Molybdenum</td>
</tr>
<tr>
<td></td>
<td>Arsenic</td>
</tr>
<tr>
<td></td>
<td>Nickel</td>
</tr>
<tr>
<td></td>
<td>Barium</td>
</tr>
<tr>
<td></td>
<td>Phosphorus</td>
</tr>
<tr>
<td></td>
<td>Beryllium</td>
</tr>
<tr>
<td></td>
<td>Potassium</td>
</tr>
<tr>
<td></td>
<td>Boron</td>
</tr>
<tr>
<td></td>
<td>Selenium</td>
</tr>
<tr>
<td>Method</td>
<td>Constituents</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Cadmium</strong></td>
<td>Silver</td>
</tr>
<tr>
<td><strong>Calcium</strong></td>
<td>Sodium</td>
</tr>
<tr>
<td><strong>Chromium</strong></td>
<td>Strontium</td>
</tr>
<tr>
<td><strong>Cobalt</strong></td>
<td>Thallium</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td>Tin</td>
</tr>
<tr>
<td><strong>Iron</strong></td>
<td>Titanium</td>
</tr>
<tr>
<td><strong>Lead</strong></td>
<td>Vanadium</td>
</tr>
<tr>
<td><strong>Magnesium</strong></td>
<td>Zinc</td>
</tr>
<tr>
<td><strong>Pesticides and PBCs by</strong></td>
<td><strong>EPA 8081A/8082</strong></td>
</tr>
<tr>
<td>4,4´-DDD</td>
<td>Endrin aldehyde</td>
</tr>
<tr>
<td>4,4´-DDE</td>
<td>gamma-BHC (Lindane)</td>
</tr>
<tr>
<td>4,4´-DDT</td>
<td>Heptachlor</td>
</tr>
<tr>
<td>Aldrin</td>
<td>Heptachlor epoxide</td>
</tr>
<tr>
<td>alpha-BHC</td>
<td>Methoxychlor</td>
</tr>
<tr>
<td>beta-BHC</td>
<td>PCB-1016</td>
</tr>
<tr>
<td>Chlordane (tech)</td>
<td>PCB-1221</td>
</tr>
<tr>
<td>delta-BHC</td>
<td>PCB-1232</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>PCB-1242</td>
</tr>
<tr>
<td>Endosulfan I</td>
<td>PCB-1248</td>
</tr>
<tr>
<td>Endosulfan II</td>
<td>PCB-1254</td>
</tr>
<tr>
<td>Endosulfan sulfate</td>
<td>PCB-1260</td>
</tr>
<tr>
<td>Endrin</td>
<td>Toxaphene</td>
</tr>
<tr>
<td>1,2,4-Trichlorobenzene</td>
<td>Benzo (g,h,i) perylene</td>
</tr>
<tr>
<td>1,2-Dichlorobenzene</td>
<td>Benzo (k) fluoranthene</td>
</tr>
<tr>
<td>1,2-Diphenylhydrazine</td>
<td><strong>Benzoic acid</strong></td>
</tr>
<tr>
<td>1,3-Dichlorobenzene</td>
<td>Benzyl alcohol</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>Bis(2-chloroethoxy)methane</td>
</tr>
<tr>
<td>2,4,5-Trichlorophenol</td>
<td>Bis(2-chloroethyl)ether</td>
</tr>
<tr>
<td>2,4,6-Trichlorophenol</td>
<td>Bis(2-chloroisopropyl)ether</td>
</tr>
<tr>
<td>2,4-Dichlorophenol</td>
<td>Bis(2-ethylhexyl)phthalate</td>
</tr>
<tr>
<td>2,4-Dimethylphenol</td>
<td>Butyl benzyl phthalate</td>
</tr>
<tr>
<td>2,4-Dinitrophenol</td>
<td>Chrysene</td>
</tr>
<tr>
<td>2,4-Dinitrotoluene</td>
<td>Dibenz (a,h) anthracene</td>
</tr>
<tr>
<td>2,6-Dinitrotoluene</td>
<td>Dibenzofuran</td>
</tr>
<tr>
<td>2-Chloronaphthalene</td>
<td>Diethyl phthalate</td>
</tr>
<tr>
<td>2-Chlorophenol</td>
<td>Dimethyl phthalate</td>
</tr>
<tr>
<td>2-Methylnaphthalene</td>
<td>Di-n-butyl phthalate</td>
</tr>
<tr>
<td>2-Methylphenol (o-cresol)</td>
<td>Di-n-octyl phthalate</td>
</tr>
<tr>
<td>2-Nitroaniline</td>
<td>Fluoranethene</td>
</tr>
<tr>
<td>Method</td>
<td>Constituents</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>2-Nitrophenol</td>
<td>Fluorene</td>
</tr>
<tr>
<td>3 &amp; 4-Methylphenol (m,p-resol)</td>
<td>Hexachlorobenzene</td>
</tr>
<tr>
<td>3-Nitroaniline</td>
<td>Hexachlorobutadiene</td>
</tr>
<tr>
<td>4,6-Dinitro-2-methylphenol</td>
<td>Hexachlorocyclopentadiene</td>
</tr>
<tr>
<td>4-Bromophenyl phenyl ether</td>
<td>Hexachloroethane</td>
</tr>
<tr>
<td>4-Chloro-3-methylphenol</td>
<td>Indeno (1,2,3-cd) pyrene</td>
</tr>
<tr>
<td>4-Chloroaniline</td>
<td>Isophorone</td>
</tr>
<tr>
<td>4-Chlorophenyl phenyl ether</td>
<td>Naphthalene</td>
</tr>
<tr>
<td>4-Nitroaniline</td>
<td>Nitrobenzene</td>
</tr>
<tr>
<td>4-Nitrophenol</td>
<td>N-Nitrosodimethylamine</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>N-Nitrosodi-n-propylamine</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>N-Nitrosodiphenylamine</td>
</tr>
<tr>
<td>Anthracene</td>
<td>Pentachlorophenol</td>
</tr>
<tr>
<td>Benzo (a) anthracene</td>
<td>Phenanthrene</td>
</tr>
<tr>
<td>Benzo (a) pyrene</td>
<td>Phenol</td>
</tr>
<tr>
<td>Benzo (b) fluoranthene</td>
<td>Pyrene</td>
</tr>
<tr>
<td>VOAs with EPA 8260B</td>
<td></td>
</tr>
<tr>
<td>1,1,1,2-Tetrachloroethane</td>
<td>Chloroform</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>Chloromethane</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>cis-1,2-Dichloroethene</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>cis-1,3-Dichloropropene</td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
<td>Dibromochloromethane</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>Dibromomethane</td>
</tr>
<tr>
<td>1,1-Dichloropropene</td>
<td>Dichlorodifluoromethane</td>
</tr>
<tr>
<td>1,2,3-Trichlorobenzene</td>
<td>Ethylbenzene</td>
</tr>
<tr>
<td>1,2,3-Trichloropropane</td>
<td>Hexachlorobutadiene</td>
</tr>
<tr>
<td>1,2,4-Trichlorobenzene</td>
<td>Isopropylbenzene</td>
</tr>
<tr>
<td>1,2,4-Trimethylbenzene</td>
<td>m,p-Xylene</td>
</tr>
<tr>
<td>1,2-Dibromo-3-chloropropane</td>
<td>Methyl ethyl ketone</td>
</tr>
<tr>
<td>1,2-Dibromoethane (EDB)</td>
<td>Methyl isobutyl ketone</td>
</tr>
<tr>
<td>1,2-Dichlorobenzene</td>
<td>Methyl tert-butyl ether</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>Methylene chloride</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
<td>Naphthalene</td>
</tr>
<tr>
<td>1,3,5-Trimethylbenzene</td>
<td>n-Butylbenzene</td>
</tr>
<tr>
<td>1,3-Dichlorobenzene</td>
<td>n-Propylbenzene</td>
</tr>
<tr>
<td>1,3-Dichloropropane</td>
<td>o-Xylene</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>p-Isopropyltoluene</td>
</tr>
<tr>
<td>2,2-Dichloropropane</td>
<td>sec-Butylbenzene</td>
</tr>
<tr>
<td>2-Chlorotoluene</td>
<td>Styrene</td>
</tr>
<tr>
<td>4-Chlorotoluene</td>
<td>tert-Butylbenzene</td>
</tr>
<tr>
<td>Acetone</td>
<td>Tetrachloroethene</td>
</tr>
</tbody>
</table>
Once the composition of the powdered carpet backing was known, a preliminary effort was made to determine which of those compounds might leach from the material when exposed to water. The powder was added to glass containers containing distilled water. Hydrochloric acid (HCl) was added to two of the containers, adjusting the pH to simulate an acidic environment where the solubility of the calcium carbonate rich material would be greater than in a neutral pH condition (Table 10).

**Table 10. Experimental conditions for determining leachate properties of powdered carpet backing**

<table>
<thead>
<tr>
<th>Container</th>
<th>Mass powered carpet backing (gm)</th>
<th>Combined volume of distilled water and HCl (l)</th>
<th>pH of solution at time of sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>85</td>
<td>6.00</td>
<td>7.2</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
<td>6.50</td>
<td>5.4</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>6.25</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Preliminary analysis was also made of the potential for leachate from the powdered carpet backing to affect the quality of a receiving water. Calcium (80%), magnesium (8%), aluminum (4%) and sodium (2%) accounted for nearly 95% of the dry weight mass of the compounds investigated (Table 11). The only organic compounds detected were Bis (2-ethylhexyl) phthalate, Butyl benzyl phthalate, and Di-n-butyl phthalate, all at mass fractions less than 0.01%. These compounds are often used as plastic softeners, and present in a wide variety of consumer products.

To investigate the mobilization of the soluble fraction of the various compounds in the backing powder, the powder was allowed to soak in distilled water with the pH adjusted to three different values using HCl. In each case, sufficient powder was added to yield a solution exceeding 10,000 mg/l. After a week, the concentration of the compounds previously identified as contained in the backing powder were determined for the supernate (Table 12).
### Table 11. Dry mass fraction of constituents in powdered carpet backing

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Result (mg/kg)</th>
<th>Constituent</th>
<th>Result (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>10,000</td>
<td>Manganese</td>
<td>76</td>
</tr>
<tr>
<td>Ammonia as NH₃</td>
<td>6.8</td>
<td>Mercury</td>
<td>0.045</td>
</tr>
<tr>
<td>Antimony</td>
<td>2</td>
<td>Molybdenum</td>
<td>1.5</td>
</tr>
<tr>
<td>Barium</td>
<td>52</td>
<td>Nickel</td>
<td>1.8</td>
</tr>
<tr>
<td>Benzoic acid</td>
<td>35</td>
<td>Nitrate as N</td>
<td>35</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl)phthalate</td>
<td>19</td>
<td>Nitrite as N</td>
<td>35</td>
</tr>
<tr>
<td>Boron</td>
<td>24</td>
<td>Orthophosphate</td>
<td>310</td>
</tr>
<tr>
<td>Butyl benzyl phthalate</td>
<td>9</td>
<td>Phosphorus</td>
<td>500</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.086</td>
<td>Potassium</td>
<td>810</td>
</tr>
<tr>
<td>Calcium</td>
<td>220,000</td>
<td>Selenium</td>
<td>3</td>
</tr>
<tr>
<td>Chloride</td>
<td>3,300</td>
<td>Silicon</td>
<td>240</td>
</tr>
<tr>
<td>Chromium</td>
<td>2</td>
<td>Sodium</td>
<td>4,700</td>
</tr>
<tr>
<td>Cobalt</td>
<td>1</td>
<td>Strontium</td>
<td>220</td>
</tr>
<tr>
<td>Copper</td>
<td>6.3</td>
<td>Titanium</td>
<td>30</td>
</tr>
<tr>
<td>Di-n-butyl phthalate</td>
<td>5.3</td>
<td>Total Kjeldahl Nitrogen</td>
<td>4,000</td>
</tr>
<tr>
<td>Fluoride</td>
<td>160</td>
<td>Total Nitrogen</td>
<td>4,100</td>
</tr>
<tr>
<td>Iron</td>
<td>1,600</td>
<td>Vanadium</td>
<td>1.3</td>
</tr>
<tr>
<td>Lead</td>
<td>1.3</td>
<td>Zinc</td>
<td>56</td>
</tr>
<tr>
<td>Magnesium</td>
<td>23,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 12. Leachate from powdered carpet backing under three pH conditions

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>pH = 7.2</th>
<th>pH = 5.9</th>
<th>pH = 5.4</th>
<th>Standard exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 &amp; 4-Methylphenol</td>
<td>ug/L</td>
<td>6.4</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>0.19</td>
<td>0.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>US Secondary MCL, CA MCL</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>6.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.96</td>
<td>ND</td>
<td>No</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0.0066</td>
<td>0.036</td>
<td>0.046</td>
<td>24</td>
</tr>
<tr>
<td>Benzoic acid</td>
<td>ug/L</td>
<td>ND</td>
<td>34</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl)phthalate</td>
<td>ug/L</td>
<td>3.3</td>
<td>4.6</td>
<td>8.0</td>
<td>8.0 &lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td>0.39</td>
<td>0.36</td>
<td>0.35</td>
<td>0.35 &lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>US Secondary MCL, <sup>b</sup>CA MCL, <sup>c</sup>Aquatic life chronic
<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>pH = 7.2</th>
<th>pH = 5.9</th>
<th>pH = 5.4</th>
<th>Standard exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyl benzyl phthalate</td>
<td>ug/L</td>
<td>ND</td>
<td>2.0</td>
<td>3.4</td>
<td>----</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>ND</td>
<td>0.00035</td>
<td>0.00063</td>
<td>No</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
<td>14</td>
<td>650</td>
<td>830</td>
<td>----</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>25</td>
<td>1400*</td>
<td>2100*</td>
<td>* CI from HCl addition</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>ND</td>
<td>0.0043</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.029</td>
<td>0.034</td>
<td>0.053</td>
<td>No</td>
</tr>
<tr>
<td>Diethyl phthalate</td>
<td>ug/L</td>
<td>6.1</td>
<td>9.9</td>
<td>12</td>
<td>----</td>
</tr>
<tr>
<td>Di-n-butyl phthalate</td>
<td>ug/L</td>
<td>ND</td>
<td>3.4</td>
<td>4.6</td>
<td>----</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>0.15</td>
<td>0.42</td>
<td>0.50</td>
<td>No</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>0.37d</td>
<td>1.8d</td>
<td>2.3d</td>
<td>d US Secondary MCL</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>1.6e</td>
<td>11e</td>
<td>20e</td>
<td>MSGP Benchmark</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.22f</td>
<td>0.32f</td>
<td>f US Secondary MCL</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.00009</td>
<td>ND</td>
<td>0.00006</td>
<td>No</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>mg/L</td>
<td>0.0091</td>
<td>0.019</td>
<td>0.021</td>
<td>----</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>0.0037</td>
<td>0.0068</td>
<td>0.0068</td>
<td>No</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>mg/L</td>
<td>2.5</td>
<td>4.6</td>
<td>5.1</td>
<td>----</td>
</tr>
<tr>
<td>Phenol</td>
<td>ug/L</td>
<td>ND</td>
<td>1.7</td>
<td>2.6</td>
<td>----</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>mg/L</td>
<td>1.8</td>
<td>2.8</td>
<td>3.2</td>
<td>----</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
<td>9.8</td>
<td>12</td>
<td>7.8</td>
<td>----</td>
</tr>
<tr>
<td>Silica</td>
<td>mg/L</td>
<td>2.7</td>
<td>3.8</td>
<td>5.5</td>
<td>----</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>65</td>
<td>82</td>
<td>82</td>
<td>----</td>
</tr>
<tr>
<td>Strontium</td>
<td>mg/L</td>
<td>0.053</td>
<td>0.74</td>
<td>0.95</td>
<td>----</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen</td>
<td>mg/L</td>
<td>17</td>
<td>12</td>
<td>13</td>
<td>----</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>mg/L</td>
<td>17</td>
<td>12</td>
<td>13</td>
<td>----</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.14g</td>
<td>0.36g</td>
<td>0.44g</td>
<td>g Aquatic life acute and MSGP Benchmark</td>
</tr>
</tbody>
</table>

In general, the concentrations increased with decreasing pH, likely resulting from the increased solubility of the calcium carbonate binder/filler in the powder as the pH decreases. However, even under these relatively extreme conditions, few of the constituent concentrations exceeded the drinking water MCLs or aquatic life freshwater quality maximums. Only aluminum and manganese concentrations exceeded primary or secondary drinking water MCLs. Hydrochloric acid added to the two pH adjusted containers is believed responsible for the high chloride concentration in the samples collected from those containers.

Direct discharge of the leachate might result in water quality impacts due to the concentrations of nitrogen compounds in all three containers, but the nitrogen could be a beneficial nutrient if the leachate was land applied. The concentration of magnesium and zinc exceeded the limit for the EPA stormwater multi-sector general permit benchmark, but these metals are very reactive with soil and could be removed with soil mantel treatment.
4. Potential Civil Engineering Applications

This chapter discusses the lab results and relates the results to the potential uses of RPC in the identified civil engineering applications of lightweight fill material, water control applications, roadway reinforcement, and lightweight composites/RPC reinforced concrete. Industry standards and requirements for these applications were also reviewed.

4.1 Lightweight Fill Materials

As part of the January 2014 California Carpet Stewardship Plan, the California Department of Transportation (Caltrans) identified that determining whether carpet recycled products are suitable fill materials is a critical element in incentivizing the market growth of secondary products made from post-consumer carpet. Geotechnical fills are used for building roadway embankments, filling in behind retaining walls, and as backfill above buried pipelines. Conventional fill materials used in construction generally include soil and gravel because these materials are locally available and have been the standard material for construction projects. However, the high density and weight of soil and gravel may be an issue for certain construction projects. Unlike soil and gravel, the use of lightweight fill materials reduces lateral loads on retaining walls and building foundations, can reduce the need for over excavation, and diminish the required amounts of structural steel and concrete wall thickness. Additionally, using lightweight fill materials on grounds with soft soils or soft clay can provide high load support while maintaining a low weight, and can be a reasonable option for stabilizing steep slopes. Based on HSU’s laboratory results of the three different forms of RPC carpet, RPC generally is lightweight and can potentially be a lightweight fill material.

Several lightweight fill options currently used in the construction industry include: pumice, expanded polystyrene, expanded shale clay, wood chips, and TDA. Research from 2005 also suggested the use of recycling plastic bottles as a lightweight geotechnical fill material. The following sections provide a brief description of these lightweight materials, include pros and cons, and compare the density of these materials with the different forms of RPC.

4.1.1 Pumice Rock

Pumice is a volcanic igneous rock that is obtained through mining operations. Because pumice has a high strength to weight ratio, about three-quarters of pumice is used annually to make lightweight construction materials such as concrete (Minerals Education Coalition, 2013). In terms of pavement design, Caltrans specifications require a soils test R-value of a minimum of 50 and a durability index of at least 35. Pumice has an R-value of 80 and a durability index of 75, which exceeds Caltrans standards (Glass Mountain Pumice, 2012).

Additionally, pumice aggregate provides up to four times the insulation value of standard aggregates or a standard concrete mix. Pumice is freeze-and-thaw cycle resistant and can reduce moisture condensation on structure walls and ceilings, making it a suitable choice for projects in colder climates and locations that experience dramatic changes in weather. Pumice also has a near-neutral pH and is fire-resistant, making it appropriate for areas that promote vegetation (Uses for Pumice, 2014). Because the density and consistency of pumice rock also varies, installers need to ensure proper compaction of the material.
4.1.2 Expanded Polystyrene (EPS)

Expanded polystyrene is a synthetic foam that is lightweight, rigid, and known for its formability properties. Unlike other lightweight fills such as shredded tires or wood chips, EPS is homogenous, which provides uniform load transfer and eliminates differential settlement. Due to the low density of EPS, the blocks can be maneuvered by hand or placed with small mechanical equipment. EPS fill can also be placed easily on projects with tight construction access where the use of larger mechanical equipment may not be feasible.

Caution must be taken during transportation and installation of the material to make sure EPS is not exposed to chemicals, heat or wind. EPS is subject to damage when exposed to certain hydrocarbon chemicals or solvents (CE News, 2014). Additionally, EPS is combustible at high temperatures and therefore should not be in the presence of open flames or high-heat equipment such as welders, even when treated with a fire retardant to avoid the rapid spread of fire. Prolonged exposure to sunlight will also deteriorate the material (VersaTech Inc., 2015). Given the lightweight nature of EPS blocks, construction stockpiles need to be tied down.

4.1.3 Expanded Shale Clay

Expanded shale clay is manufactured from shale and clay, in which expansion of the materials occurs when the raw materials are heated in a rotary kiln at high temperatures. Because of the manufacturing process, expanded shale clay is consistent and homogeneous. It is physically and chemically inert, and its ceramic properties reduce material degradation. Expanded shale clay's high angle of internal friction provides stability and strength, and its high hydraulic conductivity allows fast, free drainage (ESCS, 2008).

4.1.4 Wood Chips

Wood chips are locally available in certain areas and have been used in Washington and Minnesota for roadway embankments. Although 20-year studies have shown that wood chips provide excellent long-term performance as lightweight fill material, wood chips near the bottom of the fill may experience degradation of the wood fibers and cell walls, possibly due to bacterial activity (Washington State DOT, 1992; Minnesota DOT, 1998).

The potential effects of wood chips on the water table are problematic. As a biodegradable material, wood chips act as an eutrophication agent like algae in rivers and lakes because the biodegradation process consumes available oxygen. The leachate lowers groundwater pH, making it increasingly acidic (Alaska DOT, 2008). Therefore, barriers should be placed between wood chip fill to prevent contact with surface and groundwater for both longevity and environmental reasons. Large void spaces may cause post-construction embankment settlement problems.

4.1.5 Tire Derived Aggregate (TDA)

TDA is a 100 percent recycled material made from waste tires shredded to a specific size unique to a wide range of public works projects and other civil engineering applications. Previous studies have shown that TDA is highly permeable and allows free drainage. It also has good thermal insulation and is durable and compressible (CalRecycle, 2011).

However, there can be inconsistency in the product (i.e. exposed steel belts) which may result in more work to ensure proper compaction and screening of the material. Additionally, due to the highly elastic reload/unload response of TDA in comparison to wood chips and soil, sufficient cover must be provided in order to avoid distress of the pavement section above (Minnesota DOT, 2013;
Newcomb and Drescher, 1994). The elasticity is measured by the elastic modulus $E$, where lower values of $E$ are indicative of layer deformities. The elastic modulus for tire rubber ranges from 180 pounds per square inch (psi) to 750 psi (Beatty, 1981). The modulus of elasticity for TDA is comparable to EPS (Universal Construction Foam, 2014). As a comparison, the elastic modulus of dense, drained sands can vary from 6,000 psi to 12,000 psi (Kulhawy and Mayne, 1990). Therefore, under the same stress conditions, TDA will deform much more than soil.

### 4.1.6 Recycled Plastic Bottles

The University of Alabama performed research in 2005 to determine whether plastic bottles can be used as a lightweight geotechnical material. In the 2005 research, the recycled plastic bottles in their original post-consumer form were glued together with urethane foam adhesive, and compression tests were performed. Laboratory results showed that the density of the recycled plastic bottle fill is comparable to EPS, at 0.03 g/cm$^3$; the strength was half as strong as EPS, which is similar to the strength of soft soils (Graettinger, et al. 2005). A field installation of the plastic bottle fill was performed behind a retaining wall on a bicycle path in Alabama. The plastic bottle fill was observed over a period of nine months; there was no apparent subsidence and the plastic bottle fill was not distinguishable from the surrounding natural material.

### 4.1.7 Density of RPC Compared to other Civil Engineering Fill Materials

Figure 8 graphically illustrates the average densities of shredded PET carpet, PET carpet underlayment, and PET carpet fluff against the average densities of other traditional and lightweight fill materials that are currently used or proposed for use in the construction industry. From the lightweight fill perspective, RPC can potentially be a substitute for the traditional soil and gravel fill materials. However, the high compressibility of RPC carpet may result in settlement issues.

![Figure 8: Average Density of RPC and other Civil Engineering Fill Materials](image)

As discussed in this section, each lightweight fill material has its own set of advantages and disadvantages, including material properties, source and quality control of the material, and the difficulties associated with transportation and installation of the materials. To further investigate the performance of RPC as a fill material, it is crucial to conduct a field study to assess the behavior of

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1 Density data per CalRecycle’s Cost Benefit Assessment: Evaluation of Tire-Derived Aggregate against Alternate Fill Options for Civil Engineering Applications, June 2015 by GHD, Inc.
RPC (i.e. settlement) in bulk, and determine appropriate construction means and methods of this material in order to use it in the civil engineering and construction industry.

4.2 Water Control

Based on HSU’s laboratory results, shredded RPC and RPC fluff has high surface area, with porosity comparable to sand and gravel. Using this information, GHD hypothesizes that RPC may be used in water control applications, possibly for septic system and drainage applications, as well as for erosion control measures in storm water management.

4.2.1 Septic System and Infiltration Applications

Septic systems and infiltration applications require drainage media that has high porosity and hydraulic conductivity. Porosity describes the fraction of void space of a material, and is an important consideration when evaluating the potential volume of water the material may contain. Hydraulic conductivity describes the movement of water through the pore spaces of a material. Although porosity can be proportional to hydraulic conductivity, it is not always the case. For instance, clay soils have high porosities, but have low hydraulic conductivity because they do not release water rapidly.

The porosity of RPC compared with typical types of soil and gravel is illustrated in Figure 9. In general, shredded RPC has a higher porosity than RPC fluff. Although the porosity of the fluff was lower than the shredded RPC at equivalent loads, the fluff has porosity values similar to sand and gravel.

![Figure 9: Range of Porosity Values for RPC Compared with Soil and Gravel](image)

The hydraulic conductivities of shredded RPC and RPC fluff, as shown in Figure 6, were compared with typical types of soil and gravel are summarized in Table 13. Based on the HSU’s testing results, the hydraulic conductivity for these carpet products falls within the lower range of clean

---

2 Gravel data per Geotech Data Info (http://www.geotechdata.info/parameter/permeability.html); Sand data per Argonne National Laboratory (http://web.ead.anl.gov/resrad/datacoll/porosity.htm). TDA and PET data interpolated from Figure 5 for vertical loads of 10 and 30 psi.
sand and gravel. Saturated shredded carpet and underlayment retain more water after gravity draining, which is likely due to the extremely high surface area of the fibers in the product.

Table 13: Hydraulic Conductivities of RPC Compared with Soil and Gravel

<table>
<thead>
<tr>
<th>Hydraulic Conductivity Range, ft/day</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>90</td>
<td>14,000</td>
</tr>
<tr>
<td>Clean Sand</td>
<td>0.9</td>
<td>900</td>
</tr>
<tr>
<td>TDA</td>
<td>138</td>
<td>439</td>
</tr>
<tr>
<td>Shredded RPC and RPC Fluff</td>
<td>7.0</td>
<td>265</td>
</tr>
<tr>
<td>Silty Sand</td>
<td>0.09</td>
<td>9.00</td>
</tr>
</tbody>
</table>

Because of the lower hydraulic conductivity, shredded RPC and RPC fluff may not be a suitable material for drainage applications alone (i.e. pipe bedding or drainage for retaining wall) because there are other well-established and effective alternatives. However, RPC’s drainage properties combined with its high surface area may provide advantageous results for septic system and infiltration applications. Specifically, drain rock or media in septic systems serves as a membrane for biomat to form. The biomat is critical to allow aerobic digestion and filtration of the wastewater. Because RPC has high surface area due to the fibers, bacteria may readily adhere onto the fibers and promote aerobic digestion. As for infiltration applications, the high surface area may be effective in removing fine sediments and pollutants from urban storm water. In order to better understand the bacteriological interactions in RPC, the removal of dissolved constituents in RPC, and the effects of wastewater and storm water runoff on the longevity of RPC, it may be beneficial to install shredded PET carpet to simulate septic system applications and infiltration galleries in the field for data analysis.

4.2.2 Erosion Control

Vegetation is the most effective form of erosion control available. Erosion control products are typically manufactured from materials that are meant to slow down the surface water velocity and create a foundation for plant roots to take hold. Most erosion control products used are meant to promote vegetative growth and are biodegradable.

Based on the high surface area and water absorbency of PET carpet, RPC may serve as an effective erosion and sediment control product in storm water management. Through a literature review of the material properties of existing erosion control blankets currently in the market, temporary erosion control blankets tend to have water absorbency values ranging from 167% to 880%. As shown in Table 1, the water absorbency of shredded PET carpet and PET carpet underlayment is 206% and 131%, respectively. The water absorbency of RPC can help mitigate excess runoff if the ground is fully saturated. RPC can potentially be suitable for temporary erosion control products that are meant to be removed from the site.

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3 Gravel and soil data per Argonne National Laboratory (http://web.ead.anl.gov/resrad/datacoll/conuct.htm). TDA data per HSU reported values at 2.95 psi and 44 psi vertical load. RPC data reported at 4 and 68 psi vertical load.

4 Material and performance specifications were obtained for the following products: ECX-2 Erosion Control Blankets by EastCoast Erosion Control; RollMax BioNet C125BN, EroNet C125, and HydraMax by Tensar
In fact, GeoHay is a company based in South Carolina that currently produces erosion control products from recycled carpet fibers. Additionally, Granite Seed Company manufactures Recyclex, which is the first permanent turf reinforcement mat with fibers made from 100% recycled post-consumer goods, which include green and brown bottles. The breakdown of the types of materials used in these products were not available, but it is assumed that RPC would be a competitive substitute.

If CARE decides to further pursue the pathway of using RPC in erosion control products, additional research should be performed to obtain tensile strength values, slope design factors, and UV stability of RPC. An assessment of specific water quality/leachate constituents is also recommended, and further studies should be considered to determine the barriers that are limiting recycled carpet erosion control products from having a more substantial presence in the marketplace.

4.3 Road Surface Reinforcement

Reliance Carpet Cushion is currently manufactured for indoor usage. Carpet cushions (underlayment) are typically installed underneath carpeting to provide structural support to hold up the carpet and backing. Due to its fiber content and porosity and density values, GHD hypothesized that the carpet cushion may be suitable as a pavement reinforcing layer.

Currently in the pavement reinforcement market, there are woven and non-woven geotextiles made from polypropylene that provides filtration and separation as well as stabilization and load spreading. The MacTex® manufactured by Maccaferri comprises of both woven and non-woven needle-punched geotextile made from 100% PP staple filaments, and is used in paving applications, where it acts as a waterproofing and stress relieving membrane within the pavement structure. Hydraulic conductivity for the MacTex® is comparable to the values for the RPC underlayment shown in Table 13. Other similar products in the marketplace for asphalt overlay include: Tencate Mirafi’s MPV, US Fabrics®, and Geotex®, to name a few.

Based on a preliminary review of the existing asphalt overlay geotextiles properties, the PET underlayment may be suitable to be developed into a road surface reinforcement geotextile, and become a competitive substitute. However, tensile strength and elongation, both important criteria for geotextile performance, were not determined for the underlayment in this study; these parameters would be required in future studies, along with UV resistance, water flow rate, and permittivity, in order to determine the tolerances that the underlayment can withstand.

4.4 Lightweight Composites and Carpet Fiber Reinforced Concrete

Dr. Youjiang Wang, a professor of Polymer, Textile & Fiber Engineering at Georgia Tech, has performed research in the past on recycling post-consumer carpets specifically for use in lightweight composites.

Lightweight cement boards constructed using recycled nylon and PP carpet fibers were evaluated by Ucar and Wang (2008). The 2008 study revealed that the density of the lightweight composites ranges from 0.7 to 1.0 g/cm³, which was about 30-40 percent of the density of typical concrete. Besides being moisture and termite resistant, the lightweight composites were very tough and could be cut and fastened with ordinary tools and nails. The lightweight composites are suitable for applications such as underlayment and wall panels for buildings, as well as for outdoor structures. Research to-date have not specifically evaluated RPC in lightweight composites, but it is anticipated that RPC would produce similar results to nylon and PP fibers.
Additionally, a number of studies were conducted during the past three decades evaluating the potential of carpet fiber reinforced concrete. In particular, a field study using nylon carpet waste fibers in concrete was conducted in 1994 in Dalton, GA (Wang 1995). Although the 1-day compressive tests between the nylon reinforced concrete and plain concrete were similar, the 28-day compressive strengths of carpet fiber reinforced concrete was lower. An advantage of the carpet fiber reinforced concrete is that it exhibits a high flexural strength and ductile behavior whereas the plain concrete is more brittle. The 1995 study indicated that because cracking, spalling and scaling types of deterioration are related to the brittleness of concrete, using carpet fiber reinforced concrete may produce structures such as columns, bridge decks and highway barriers more reliable and longer lasting. Similar results are expected for RPC fiber reinforced concrete.

Although there has been extensive research and a field study using carpet fibers in construction, carpet fiber reinforced concrete has not achieved widespread application to-date. This may be because there are competing lightweight concretes in the industry, or that the tradeoff between concrete compressive strength and ductility are not widely accepted in the industry due to existing design guidelines and building codes.

If CARE decides to pursue the pathway of RPC lightweight composites and RPC reinforced concrete, additional research should be performed to determine if PET fibers provide similar strength to concrete like nylon fibers, a cost-benefit analysis should be considered, and additional studies should be conducted to determine the barriers that are limiting carpet fiber reinforced concrete from having a more substantial presence in the marketplace.

### 4.5 Other Civil Engineering Applications Proposed for Further Consideration

This study included laboratory testing of water leachate constituents and material properties such as porosity, hydraulic conductivity, compressibility and density of shredded RPC, RPC fluff, and RPC underlayment. Based on the test results, potential civil engineering applications with RPC include: lightweight fill, septic system media, erosion control, roadway surface reinforcement, and lightweight composites/concrete. To broaden the scope of civil engineering applications, other mechanical, physical, and chemical properties could be tested, including:

- Acoustic transmission
- Vibration dampening
- Flammability
- Electrical resistance
- Corrosion resistance
- Seismic performance (direct shear, triaxial shear, pull-out test, friability)
- Heat and insulation

As for the powdered carpet backing, only a leachate analysis was performed in this study. In order to determine whether powdered carpet backing can be used in civil engineering applications, additional research will need to be performed.
5. Conclusions and Recommendations

5.1 Conclusions on Water Quality and Regulatory Requirements

5.1.1 Hazardous Material Testing

Shredded carpet (RPC that includes backing and fluff) was the only carpet sample analyzed by the WET and TCLP tests and was assumed to be a representative sample of RPC. The WET and TCLP tests concluded that RPC is not considered a hazardous material.

5.1.2 Leachate Analysis

Leachate water quality was determined by soaking carpet samples of shredded carpet, fluff and underlayment in distilled water for variable amounts of time. Leachate water quality results show that the material is relatively benign. Only 22 of the 115 constituents examined were determined to have concentrations above the method detection limit. Among these, only 7 approached (within 80%) the existing regulatory limits examined, and only antimony exceeded the CA MCL. The presence of antimony was expected because it is a catalyst in the synthesis for PET used to make drinking water bottles (Duh 2002), and recycled into both the PET face fiber and carpet underlayment.

As for the powdered carpet backing leachate, only 43 of 195 constituents examined were determined to have concentrations above the MDL. Direct discharge of the leachate might result in water quality impacts due to the concentrations of nitrogen compounds, magnesium and zinc, but those could be removed with soil mantel treatment.

Generally speaking, leachate from shredded RPC samples contained both higher concentrations of most constituents and a greater number of regulatory exceedances than RPC underlayment or RPC face fiber samples. However, rinsing of the shredded carpet via soaking in distilled water seemed to improve leachate water quality by 22-99%, with a median of 69%, indicating that a large portion of constituents were surface-bound and soluble, allowing their effective removal with a “first flush” of water.

Furthermore, it is important to note that this laboratory investigation evaluated PET carpet that filled a container and submerged in water for a period of 1 to 2 months. In actual field installations, it is not anticipated that the material will experience such a high density in standing water for such a long duration. Additionally, the surfaces of soil particles often are chemically reactive and provide multiple means by which contaminants in water, including heavy metals, can be adsorbed by soil particles and effectively removed from the water. Therefore, the water quality results, especially in the case of antimony, may be the worst-case scenario. Field installations are highly recommended to determine whether the levels of antimony continue to exceed regulatory limits.

5.2 Chemical and Engineering Considerations

An additional chemical consideration for PET carpet is the presence of additives adsorbed to the surface of the face fiber. These additives include carpet additives introduced to the carpet during the manufacturing process, and chemical exposure from the surrounding environment during the carpet life span. These chemicals are more difficult to quantify because each PET carpet is typically exposed to different environments. Testing on new material can also determine whether the constituents that were detected originated from the carpet manufacturing or from exposure the carpet had during its previous life as a floor covering.
Furthermore, it is unknown whether the samples tested in this study are representative of the industry. If different manufacturers use a different process and/or apply different additives to the carpet, then the leachate results may differ. It is important to determine the tolerance of RPC in civil engineering applications given the range of variations in the material.

5.3 Potential Civil Engineering Applications and Recommendations

This feasibility study was the first phase (Phase I) to investigating and establishing a potential market for RPC. RPC material properties were obtained through laboratory tests and evaluated for suitability in selected civil engineering applications. Material properties obtained from this study include density, water holding capacity, compressibility, hydraulic conductivity, and porosity values of the shredded RPC, RPC fluff, and RPC underlayment.

Based on laboratory results, background research of existing literature, and a review of industry-related products, GHD recommends conducting further research on the following civil engineering applications of RPC:

1. **Septic systems/ infiltration**
   Septic system/ infiltration applications using shredded RPC and RPC fluff are recommended for further research including an in-situ pilot study. RPC's drainage properties combined with its high surface area may provide advantageous results for biomat formation in septic system and infiltration applications.

2. **Lightweight fill applications**
   Further research and in-situ pilot studies are recommended for lightweight fill applications using shredded RPC, RPC underlayment, and RPC fluff. Because the density of RPC is lower than that of conventional fill materials like soil and gravel, RPC can potentially be a suitable lightweight fill material to be used in embankments or as retaining wall backfill material.

3. **Road surface reinforcement applications**
   Roadway surface reinforcement applications are also recommended for further analysis and pilot studies because the fiber content, porosity and density values of the RPC underlayment may be suitable as a pavement reinforcing layer.

4. **Erosion control and lightweight composites/concrete**
   Lightweight composites/concrete using carpet fiber has already undergone extensive research, and erosion control with recycled carpet is already a manufactured product. Because these products have not gained widespread traction to-date, GHD recommends CARE to consider developing cost-benefit analyses and/or conducting future studies to determine the obstacles that are limiting the presence of recycled carpet erosion control products and lightweight recycled carpet concrete in the market.

To broaden the scope of civil engineering applications using RPC, additional mechanical, physical and chemical properties could be tested, in particular, when developing specific civil engineering applications. Types of testing include:

- Acoustic transmission
- Vibration dampening
- Flammability
- Electrical resistance
- Corrosion resistance
- Seismic performance (direct shear, tri-axial shear, pull-out test, friability)
- Heat and insulation
- Tensile Strength and elongation
- UV Resistance
- Water flow rate through material
- Permittivity

As for the powdered carpet backing, only a leachate analysis was performed in this study. In order to determine whether powdered carpet backing can be used in civil engineering applications, additional research will need to be performed.

5.4 Next Steps

Phase II, establishing potential markets for RPC materials in civil engineering applications, involves conducting further research, and focuses on implementing pilot studies with the three identified civil engineering applications of RPC:

1. Septic systems/infiltration
2. Lightweight fill applications
3. Road surface reinforcement applications

Implementing RPC pilot studies for these civil engineering applications would allow scientists and engineers to better understand the in-situ performance of RPC, including water quality, rate of settlement, bacteriological interactions, filtration effectiveness, and tensile behavior in asphalt overlays. The pilot studies would require the establishment of partnerships with research institution and appropriate industries or municipalities.

Implementing pilot studies and collaborating with various industries and municipalities would allow CARE to further understand the benefits of RPC and initiate market development efforts to highlight the uses and benefits of RPC material in civil engineering applications.

Table 10 summarizes the physical and chemical properties tested during this feasibility study, and the civil engineering applications recommended for future study. Through continued research and development, CARE and CalRecycle would be able to identify potential RPC uses, develop an outreach plan, and develop an incentive plan/grant program to promote the establishment and sustainability of new RPC markets.
### Table 14: Summary of Laboratory Tests Performed and Potential Civil Engineering Applications for RPC

<table>
<thead>
<tr>
<th>RPC Type</th>
<th>Physical Properties Testing</th>
<th>Hazardous Material</th>
<th>Leachate Analysis</th>
<th>Civil Engineering Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Density</td>
<td>Water Holding Capacity</td>
<td>Compressibility</td>
<td>Porosity</td>
</tr>
<tr>
<td>Shredded RPC (Combined RPC Face Fiber and backing)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>RPC Face Fiber</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>RPC Underlayment</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Powdered Carpet Backing</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Legend**

- **X**: Laboratory tests or civil engineering applications investigated under this feasibility study (Phase I)
- **-**: Not Tested/Not Applicable
- ****: Recommended for future pilot study (Phase II)

**Notes:**

1. For physical properties testing, initial testing was performed utilizing existing testing equipment at the HSU facility. Due to the physical constraints of some of the materials, not all physical property tests were performed on every type of RPC material.
2. For hazardous material tests, shredded carpet (RPC that includes backing and fluff) was the only carpet sample analyzed by the WET and TCLP tests and was assumed to be a representative sample of RPC.
3. Lightweight composites/concrete using carpet fiber has already undergone extensive research, and erosion control with recycled carpet is already a manufactured product. Because these products have not gained widespread traction to-date, GHD recommends CARE to consider developing cost-benefit analyses and/or conducting future studies to determine the obstacles that are limiting the presence of recycled carpet erosion control products and lightweight recycled carpet concrete in the market.
4. Only a leachate analysis was performed for powdered carpet backing; civil engineering applications of powdered carpet backing were not analyzed, but there may be potential for powdered carpet backing to be an additive to lightweight composites/concrete or similar applications. Further research is recommended.
6. References


<http://www.mineralseducationcoalition.org/minerals/pumice>


<http://www.dot.state.mn.us/research/TS/2013/201320.pdf>


<http://www.wsdot.wa.gov/research/reports/fullreports/239.1.pdf>

Appendix A – Manufacturing of PET Carpet Fibers
Chemistry and Manufacturing of PET

Structure and Properties of PET

Polyethylene terephthalate (PET) is a partially aromatic thermoplastic polymer of the polyester family. It is also known as “PETE” in recycling, and simply “polyester” in the textile industry (Bartolome et al. 2012). It is sold under a variety of trade names, such as Rynite, Mylar, Arnite and Hostadur. The repeating unit structure of PET consists of an aromatic ring linked via an ester group to a dimethylene unit, as shown in Figure 1.

Due to the presence of the rigid aromatic ring and short carbon chain, PET has high stiffness and can form large crystalline domains when stretched (Fairgrieve 2009). These attributes further impart a high melting temperature, good strength, light weight, good barrier properties and crease resistance. PET also exhibits high chemical and thermal resistance, making it popular for a variety of applications, which include food and beverage containers, fibers and textiles and films (Park and Kim 2014). As a thermoplastic, PET exhibits a glass transition temperature \( T_g \) of 72 °C, well below its melting temperature \( T_m \) of approximately 260°C. This makes PET amenable to a variety of processing conditions necessary to impart desired properties. The primary processes for virgin PET are extrusion (films, sheets and large objects), injection molding and blow-molding (bottles) (Fradet and Tessier 2003; Awaja and Pavel 2005). PET dominates the global synthetic fiber market (Park and Kim 2014), is the favorite packaging material for water and soft drinks world-wide (Welle 2011), and is one of the most important engineering polymers (Awaja and Pavel 2005). Various properties useful for the discussion of PET are included in Table 1.

Table A-1: Summary of PET chemical and physical properties\(^{(a)}\)

<table>
<thead>
<tr>
<th>Molecular weight of repeat unit (g/mol)</th>
<th>( T_g ) (°C) (^{(b)})</th>
<th>( T_m ) (°C) (^{(c)})</th>
<th>Density (g/cm(^3))</th>
<th>M Range (g/mol) (^{(d)})</th>
<th>Intrinsic Viscosity (IV) (dl/g) (^{(e)})</th>
<th>Breaking Strength – Tensile (MPa)</th>
<th>Young’s Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>192</td>
<td>72</td>
<td>255-265</td>
<td>1.33</td>
<td>30,000-80,000</td>
<td>0.45 – 1.2</td>
<td>50</td>
<td>1700</td>
</tr>
</tbody>
</table>

\(^{(a)}\) PET properties from: (Awaja and Pavel 2005), (Fradet and Tessier 2003), (Spinace and De Paoli 2001), (Venkatachalam et al. 2012).

\(^{(b)}\) \( T_g \): Glass transition temperature. This value is most commonly given, although the range of 69-115 °C has been reported.

\(^{(c)}\) \( T_m \): Melting temperature

\(^{(d)}\) Here, M refers to weight-average molecular weight

\(^{(e)}\) dl/g = deciliters per gram. IV depends directly on molecular weight.

Appendix A1
Synthesis of Virgin PET

Much of the commercial PET synthesis currently used was derived from the first report of polyester synthesis in the 1930s by Carothers at DuPont. The generalized reaction schemes and reagent structures and are shown in Figure 2.

**Figure A-2: General reaction scheme for PET synthesis**

PET synthesis can occur in one to three steps, depending on the target molecular weight. Typically, synthesis begins with the formation of the active monomer bis-(2-hydroxyethyl) terephthalate (BHET). BHET is formed by either condensation of EG and terephthalic acid (TPA) or transesterification of EG and dimethyl terephthalate (DMT). Then, DMT reacts by polycondensation with an excess of EG to form PET and a molecule of water. This second step is conducted under high temperature (>200°C) and low pressure (< 50 Pa), typically yielding PET with a molecular weight of 15,000-25,000 g/mol. To achieve the higher molecular weights (> 30,000 g/mol) required for bottle-grade PET, solid-state polymerization (SSP) is required as a third step. (Pang, Kotek, and Tonelli 2006; Awaja and Pavel 2005; Venkatachalam et al. 2012; Fradet and Tessier 2003)

**Synthetic Additives: Catalysts and Co-monomers**

Catalysts are employed during the industrial PET syntheses described above. The purpose of catalysts is to increase the rate, reduce side reactions and lower the energy cost of making PET. The most common and important industrial catalyst is antimony trioxide (Sb$_2$O$_3$), as it has good catalytic activity and does not add color to the finished polymer (Duh 2002). Catalysts based on other metals have been reported to a lesser extent. These include germanium, cobalt, titanium and aluminum (Park and Kim 2014; Thiele 2001).

Copolymerization with a small fraction of monomers other than terephthalate esters can be employed to further tune the physical properties of PET, and improve dyeability, charging issues and increase processability (Pang et al. 2006). For instance, co-monomers derived from 2,6-naphthalic acid and isophthalic acid can be used improve the barrier properties of PET, an important parameter in bottle production (Awaja and Pavel 2005).
Chemical Degradation and Depolymerization of PET

Exposure of polymers to environmental conditions over time will result in the alteration of their chemical, physical and thermal properties (Venkatachalam et al. 2012). In addition, degradation can result in the release of degradates and other impurities previously trapped in the polymer matrix. Both of these effects have consequences on the feasibility of using recycled PET carpet fibers in civil engineering applications. Environmental exposure can come in the form of contact with water, elevated temperatures, sunlight and interaction with organisms. Some potentially relevant PET degradation reactions are described below.

- **Hydrolytic Degradation**
  Hydrolysis refers to reaction with water. While it is true that PET bottles are slow to degrade and are considered environmentally persistent, carpet fiber made from recycled PET bottles has a higher surface area and contains more impurities than virgin PET, making it more susceptible to degradation. Due to the presence of the ester group in the polymer backbone, PET is susceptible to hydrolysis, especially in acidic or basic conditions. Hydrolysis is known to occur at temperatures exceeding 100°C for water at pH 7. At temperatures below 120°C, hydrolysis is considered to occur at rates many times faster than thermal degradation (Fairgrieve 2009).
  Hydrolysis and other solvolytic degradation reactions constitute the primary route for chemical recycling of PET, where the polymer is completely broken down to its small-molecule components. It is also studied as an unwanted side-reaction that occurs during both synthesis and materials processing of virgin PET.

- **Thermal Degradation**
  High temperatures can results in the degradation when oxygen is either absent (thermal degradation) or present (thermo-oxidative degradation). Both require high temperatures, and may occur above 250 °C (Venkatachalam et al. 2012).

- **Photodegradation**
  Photodegradation involves reactions undergone as a result of light absorption. The aromatic ring in the polymer chain lends PET to higher light adsorption than non-aromatic polymers, such as Nylon-6, Nylon-6,6 or saturated polyolefins. PET absorption is strongest at wavelengths between 254 and 313 nm, which overlaps with the high-energy (UV) band of the solar spectrum (Fairgrieve 2009). Photodegradation of PET leads to the release of various by-products, and causes the polymer to yellow and embrittle.

- **Biodegradation**
  Biodegradation involves chemical alteration of PET resulting from biological consumption and processing. No organisms were known to biodegrade PET prior to 2015, when it was discovered that has certain bacteria found at a bottle recycling facility could survive using PET as its sole energy source. This degradation mechanism should be considered under only very specific and well-characterized conditions.
References


Appendix B – Brainstorming Session Notes
### Table B-1 Potential Civil Engineering Applications

<table>
<thead>
<tr>
<th>Category</th>
<th>Possible Product Use</th>
<th>Media that PET Carpet can Potentially be Placed in</th>
<th>Properties Needed (1)</th>
<th>Concerns/Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Control</td>
<td>Infiltration Galleries</td>
<td>Soil, water (submerged), air, metals (mercury, zinc), TDS</td>
<td>Void Ratio, Density (dry weight vs wet weight), Compression, unit weight and buoyancy</td>
<td>Will PET carpet hold water? How much pressure is needed to overcome capillary action?</td>
</tr>
<tr>
<td></td>
<td>Drainage areas for retaining walls</td>
<td>Soil, concrete or masonry</td>
<td>Hydraulic conductivity, saturation, compressibility</td>
<td></td>
</tr>
<tr>
<td>Fill Material 1,3</td>
<td>Embankments similar to use of TDA</td>
<td>Soil</td>
<td>Hydraulic conductivity, saturation, compressibility, exothermic behavior</td>
<td></td>
</tr>
<tr>
<td>Reinforcement</td>
<td>Erosion Control with vegetative mat - permanent application; lightweight alternative to riprap</td>
<td>Soil</td>
<td></td>
<td>For temporary applications, there may be regulatory parameters, including biodegradation requirements</td>
</tr>
<tr>
<td>Roadway 4</td>
<td>Additive to asphalt, binder or concrete as filler to produce lightweight concrete</td>
<td>Air, Asphalt, concrete, or binder; Oil and gasoline vapors, UV*, water (surface runoff), varying temperatures</td>
<td>Temperature is approximately 300°F for asphalt. What temperature range would be suitable?</td>
<td>Will PET carpet cool down along with binder, or will it break down? How much PET carpet is needed to mix in before it can compromise strength of concrete?</td>
</tr>
<tr>
<td>Water Quality</td>
<td>Filtration for remedial extraction</td>
<td>Oil, water, VOCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td>Similar to rubberized concrete used in asphalt</td>
<td>Concrete, asphalt</td>
<td>Sound damping properties</td>
<td></td>
</tr>
<tr>
<td>Seismic</td>
<td>Liquefaction Application</td>
<td>Soil</td>
<td>Direct shear; triaxial sheer, compressibility; pull-out test; friability</td>
<td></td>
</tr>
<tr>
<td>Structural</td>
<td>Roofing (felt under shingle)</td>
<td>Tar, UV*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insulation</td>
<td>Soil, air</td>
<td>Heat index, melting point</td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>Use of bacteria to degrade PET in landfills</td>
<td>Soil, water, air, metals (mercury, zinc), TDS</td>
<td>Byproduct is thalate. How can we capture thalate and use it in civil engineering applications?</td>
<td></td>
</tr>
</tbody>
</table>

1 Laboratory tests will be performed in accordance with ASTM methods as applicable. Because ASTM methods are generally written for soil, modifications may be required to accurately determine the material properties of PET. Where will test methods deviate? Additionally, HSU may not be able to perform direct shear tests; GHD’s internal lab has capabilities. Chris Trumbull to develop list of geotechnical tests.

2 A benefit of mixing with soil or concrete is its lightweight property. The carpet may not be a good reinforcement without undergoing a lot of processing. If woven material is available, then reinforcement properties may be achieved.

3 Soil density ranges between 100-125pcf, and the allowable soil bearing varies from 1000 psf to 5000 psf

4 pH range for first flush: 5-9

* UV testing will not be performed during this feasibility study, but can be suggested for future research
Appendix C – HSU Laboratory Results on PET Carpet
**Introduction**

Evaluating potential reuse pathways for recycled PET carpet requires understanding the physical properties of the material, and the potential water quality impacts of the leachate should the material come into contact with water. In this study, some physical properties and the leachate water quality characteristics were determined for four different recycled PET carpet products: shredded carpet, carpet fluff, carpet underlayment and powdered carpet backing.

The shredded carpet was delivered in a 3 cubic yard sack. The material was clean and showed little sign of wear. To simulate sizes that would be easily managed in civil engineering applications, the material was hand sorted, retaining pieces that were between 1 inch and 12 inches long (Figure 1a). The carpet fluff, which consists of carpet fibers without the backing, was delivered in a 700 pound compressed bale (Figure 1b). The material was separated out of the bale and hand “fluffed” to produce a product closer to uncompressed carpet fibers (Figure 1c). The carpet underlayment was manufactured from recycled carpet fluff using needle stitching and partial heat fusion of the surface of the mat. The underlayment was delivered in a roll and cut into smaller pieces for easier handling (Figure 1d). Five pounds of recycled powdered carpet backing was provided for testing. The coarse, powdery material (Figure 1e), which consists of binders and fillers, is collected as PET fibers are recovered from recycled carpet.

Physical properties, including density, porosity, water holding capacity, compressibility, recovery from loads, and hydraulic conductivity were determined for the carpet materials under a variety of loading conditions. The concentration and per unit mass loading of a wide range of organic and inorganic water quality constituents of leachate from each of these recycled carpet products was also determined. Experimental procedures and the results of the experiments are presented in the sections that follow.
Figure 1  (clockwise from upper left).  a) Shredded carpet pieces. b) Bale of compressed carpet fluff. c) Expanded fluff as tested. d) Carpet fiber underlayment. e) Powdered carpet backing (center inset).
Experimental Methods

Methodologies for Determining Physical Properties of Carpet Products

Water holding capacity

The water holding capacity of the carpet and carpet underlayment was determined by soaking the oven-dried material in water for 24-hours, then allowing the material to gravity drain. The difference in weight between the pre-soak and post-gravity draining was recorded. Three 1-foot² pieces of carpet underlayment and two sets of 25 pieces of shredded carpet were used in this experiment.

Density

The density of the recycled carpet products was determined using the water displacement technique. The shredded carpet and carpet underlayment density was determined for three carpet samples (each approximately 77 gm) and four underlayment samples (each approximately 20 gm) after oven drying the pieces being tested. Three different determinations of the density were made for a single, 37 kg carpet fluff sample. The fluff sample was not oven dried prior to density testing.

Compressibility, porosity, and hydraulic conductivity

A large diameter compression apparatus that was designed and fabricated specifically for testing tire derived aggregate (TDA) under loads equivalent to 100 feet of soil fill (115 psi) was used to determine the compressibility, porosity, and hydraulic conductivity of shredded carpet and carpet fluff. The compression cylinder has a 29.7 inch inside diameter, and can hold a 30-inch deep layer of sample. The vertical loading force applied to the sample is measured by four load cells (pressure transducers), each with a 30,000 lbf capacity (Figure 2). The load cells rest on the solid bottom of the cylinder, separated from the carpet material by a perforated steel plate (Figure 3). A steel piston (Figure 4), driven by manually operated hydraulic bottle jacks (Figure 5), provides the loading force on the sample. The entire apparatus rests on a 4 foot square digital scale with a 3,000 lbf capacity and an accuracy of ±1.0 lbf. Water enters and leaves the cylinder via a fitting near the base of the unit. Water can also be added to the top of the cylinder and a constant head can be maintained by adjusting the inflow rate to exceed the outflow at the bottom, resulting in an overflow along the top lip of the cylinder.
Figure 2. Load cells (transducers) at the bottom of the compression cylinder used to measure the applied vertical stress.

Figure 3. Perforated plate resting on load cells that support the sample to be tested.
Figure 4. Piston resting on the sample inside the compression cylinder.
Figure 5. Hydraulic jacks resting on wooden and steel spacers applying load to compression piston.
The general procedure for using this apparatus is to measure the weight and volume of the sample added (shredded carpet or fluff). With the sample under a load ranging from 230 to 39,505 lbs. (0.33 to 57 psi), water is slowly added to the cylinder from the bottom, expelling any trapped air (Figure 6). The weight of the water required to fill all of the voids in the sample is measured, and the volume of the water computed given the water temperature. The porosity of the sample is then computed given the volume of water and the volume of carpet product sample.

The hydraulic conductivity is computed after measuring the flow rate of water passing through a known thickness of sample under constant head conditions. For each load condition, the flow rate was measured at least three times for each of four different head values. Finally, the compressibility of the sample can be determined under each load condition by determining the change in volume resulting from the change in load. Once data related to the maximum load on the sample is recorded, the load is released and the change in the compaction of the material is noted over a 24-hour period (Figure 7).

Four different experiments were conducted with the compression apparatus (Table 1). The first three experiments had a shredded carpet sample (Figure 8) and the fourth had a carpet fluff sample (Figure 9). The three experiments conducted with shredded carpet differed in their pre-loading. The shredded carpet in Experiment 1 was loose filled (no preloading). The carpet sample used in Experiment 2 experienced preloading of 3.5 psi (500 lb/sq. ft), and a pre-loading of 6.2 psi (890 lb/sq. ft) was used in Experiment 3. A fourth experiment was conducted with a carpet fluff sample, which was subjected to the same 6.2 psi pre-load as used in Experiment 3. In Experiments 2, 3, and 4, the preloading was applied repeatedly as successive six-inch thick layers of sample were added to the cylinder. The pre-loading forces were within the range of 500 to 1600 lb/sq. ft commonly used when placing fill material in construction projects.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Sample material</th>
<th>Preloading (psi)</th>
<th>Sample weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shredded carpet</td>
<td>0</td>
<td>95</td>
</tr>
<tr>
<td>2</td>
<td>Shredded carpet</td>
<td>3.5</td>
<td>141</td>
</tr>
<tr>
<td>3</td>
<td>Shredded carpet</td>
<td>6.2</td>
<td>166</td>
</tr>
<tr>
<td>4</td>
<td>Fluff</td>
<td>6.2</td>
<td>81</td>
</tr>
</tbody>
</table>
Figure 6. Water filled to the level of the compressed sample.

Figure 7. Compressed sample after the load is removed.
Figure 8. Compression cylinder filled with shredded carpet.

Figure 9. Compression cylinder filled with carpet fluff.
Methodologies for Determining Carpet Product Leachate Water Quality

Potential uses of recycled carpet products include situations where the material would be intermittently or continuously exposed to water. To evaluate the potential impact that the leachate from the carpet product might have on a receiving water, an experiment was conducted that exposed the material to water for an extended period. Samples of shredded carpet, carpet fluff, and carpet underlayment were placed in glass jars filled with distilled water (Figure 10). The leachate from each jar was collected after one month, and the carpet leachate was again sampled after two months of soaking. To investigate the quality of the leachate after experiencing a “first-flush”, a carpet sample that had been soaking for two months was drained, and then the jar was again filled with distilled water. After soaking for another month, a leachate sample was collected from this jar. All of the leachate samples were analyzed for a variety of water quality constituents, ranging from common organic and inorganic compounds to a wide assortment of volatile and semi-volatile compounds. A complete list of all water quality constituents analyzed and the associated detection limits is given in Appendix A.

In addition to the samples of leachate from the carpet product soaking in distilled water, a Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) analysis was performed on a shredded carpet sample. Both the TCLP and WET methods are used as part of a protocol to determine whether a material is a hazardous waste. The US EPA developed the TCLP method, and the WET method was originally developed by the State of California. Both methods involve an acid leachate extraction process to simulate the situation in a setting such as a landfill. The methods differ from one another by the acid used in the extraction, the length of time the material is subject to the acid, and by the water quality constituents examined.

The powdered carpet backing material was treated a bit differently than the other recycled carpet products. While the material was reported by the supplier to be primarily calcium carbonate and latex adhesives, the actual composition of was unknown. Therefore, the dry mass composition of the material was determined for each of the constituents listed in Appendix B. Once the composition of the material was known, a preliminary effort was made to determine which of those compounds might leach from the material when exposed to water. The powder was added to glass containers containing distilled water. Hydrochloric acid was added to two of the containers, adjusting the pH to simulate an acidic environment where the solubility of the calcium carbonate rich material would be greater than in a neutral pH condition (Table 2).
Figure 10. Glass jars filled with shredded carpet (top), fluff (bottom left), and underlayment (bottom right).

Table 2. Experimental conditions for determining leachate properties of powdered carpet backing.

<table>
<thead>
<tr>
<th>Container</th>
<th>Mass powered carpet backing (gm)</th>
<th>Combined volume of distilled water and HCl (l)</th>
<th>pH of solution at time of sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>85</td>
<td>6.00</td>
<td>7.2</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
<td>6.50</td>
<td>5.4</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>6.25</td>
<td>5.9</td>
</tr>
</tbody>
</table>
Results and Discussion

Physical Properties of Carpet Products

Water Adsorption of the Carpet

Shredded carpet pieces and carpet underlayment were tested for water adsorption. After a 24-hour soak and a 15 minute gravity drain, the water adsorption of the shredded carpet varied between 145% and 344%, with an average value of 206% for the two, 25-piece samples (Table 3). The carpet pieces in the samples varied considerably in size and in the type of backing material, which might account for the wide variation in water adsorption values observed. The carpet underlayment water adsorption rate was less than that of the shredded carpet and it required a longer gravity drain time to reach an equilibrium water content. The carpet underlayment had an average 131% increase in the mass after 24 hours of soaking and an hour of gravity draining (Table 3). The differences in the drain time and water adsorption rates may be a consequence of the heat treatment that fuses some of the fibers and the less dense nature of the fibers in the underlayment compared to the carpet.

Density

The density of the recycled carpet products was determined using the water displacement technique. The average observed density of the shredded carpet and underlayment was 1.19 g/cm³ and 1.01 g/cm³ respectively (Table 3). The density was expected to be higher for the carpet compared to the underlayment since the carpet has a relatively heavy calcium carbonate backing. The density of the carpet fluff was determined to be 0.52 g/cm³, about half that of the carpet pieces and underlayment (Table 3). This result was surprising since the underlayment is manufactured from the fluff. The higher density of the underlayment compared to the fluff may be due to the heat treatment the fluff receives which fuses together the fibers in the top and bottom surface of the material. The underlayment may also have more residual from the dense carpet backing compared to the fluff, which would increase the underlayment density. Other differences in the fluff and underlayment samples include mass of the material tested and the preparation the sample received prior to testing. The fluff mass tested was nearly 100 times larger than the underlayment and the fluff was not oven dried prior to testing. However, neither of these conditions is believed to be responsible for the differences between the measured fluff and underlayment density.
Table 3. Water absorption capacity and density of recycled carpet products.

<table>
<thead>
<tr>
<th>Material</th>
<th>Water absorption (% increase in mass)</th>
<th>Average measured density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shredded carpet</td>
<td>206</td>
<td>1.19</td>
</tr>
<tr>
<td>Carpet fluff</td>
<td>Not tested</td>
<td>0.52</td>
</tr>
<tr>
<td>Carpet underlayment</td>
<td>131</td>
<td>1.01</td>
</tr>
</tbody>
</table>

**Compressibility, porosity, and hydraulic conductivity**

The compressibility, porosity, and hydraulic conductivity of shredded carpet and carpet fluff were determined under loads ranging from 230 to 39,505 lbs. (0.33 to 57 psi). In addition, once the maximum load on the sample was reached, the load was released and the change in the compression of the material was noted over a 24-hour period. Four different experiments were conducted with the compression apparatus, with the first three having a shredded carpet sample and the fourth having a carpet fluff sample (Table 1). The three experiments conducted with shredded carpet differed in their pre-loading (vertical load applied during the fill).

The three carpet samples exhibited similar compressibility (strain) when loaded (Figure 11). In Experiment 1, the carpet was loose filled in the test chamber and subsequently compressed at very small loads. In this experiment, the carpet sample compressed by more than 50% under a load of 1 psi and approximately 70% at a load of 10 psi. The compression apparatus is unable to test a sample beyond approximately 70% compaction, therefore Experiment 1 ended with a maximum load of 11.5 psi.

The stress-strain relationship of the preloaded samples in Experiments 2 and 3 were very similar, and the samples both exhibited less stain than the Experiment 1 sample at similar loading. The difference in the preloading (3.5 psi vs. 6.2 psi) appears to be responsible for the small difference in strain between the Experiment 2 and 3 shredded carpet samples. The response of the carpet fluff to loading follows the same trend as the carpet, but fluff has approximately 10% higher percent compression at comparable vertical loading rates than the carpet in Experiment 3 (Figure 11). Up to the maximum load tested (68 psi), carpet and fluff are considerably more compressible than TDA. For example, at a vertical load of 60 psi, the vertical strain on the carpet is approximately 70%, while the strain on the TDA as reported by Finney et al. (2013) is less than 60%.
Figure 11. Vertical stress in recycled carpet products and TDA resulting from applied load.
Measuring the change in the strain after a compressive load is removed indicates that fluff may recover more quickly than, but not as completely as shredded carpet (Figure 12). After releasing the 31 psi load in Experiment 4, the carpet fluff strain immediately decreased from 73% to 57%. The remaining rebound occurred more slowly, with the strain reaching 51% 16 hours after releasing the load. After 18.5 hours, the strain was still 51%, indicating that further changes were unlikely. In Experiment 2, after releasing the 57 psi load, the shredded carpet rebounded immediately from 71% to 61% strain. While this initial recovery was less, further reductions in strain were greater than observed in the fluff. The strain in the carpet sample was reduced to 46% after 19 hours and was essentially unchanged when measured again 26 hours after the load was released. The differences in the strain recovery observed between shredded carpet and carpet fluff may be due to the differences in the ultimate load applied. Additional testing with uniform loading would be necessary to investigate this behavior further, and to determine whether the recovery depends on the length of time the load is applied prior to it being released.
The relationship between the load applied and the porosity of the shredded carpet and fluff is similar to the behavior observed for the compressibility of the materials (Figure 13). At loads less than 5 psi, the porosity of the carpet products varied between 56% and 87%. With increasing load, the porosity rapidly decreased. At a 40 psi load, the porosity of the shredded carpet with a 3.5 psi and 6.2 psi preload was approximately 30% and 42% respectively. The porosity of the fluff was lower than the shredded carpet at equivalent loads. For example, at 31 psi, the 6.2 psi preloaded fluff had a porosity of 26%, while at the same load the carpet had a porosity of 45%. The behavior of the shredded carpet porosity to loading is remarkably similar to that of TDA. While Finney et al. (2013) did not determine the porosity of TDA at the intermediate loads that were applied to the carpet, the interpolated response curve of TDA porosity to load applied appears to be between the curves for the two preloaded shredded carpet samples (Figure 13).
The change in hydraulic conductivity to changes in loads applied was very similar for shredded carpet and fluff at all preloading conditions (Figure 14). Considering all of the computed values from the four experiments together, the hydraulic conductivity ranged from 265 ft/day at 4 psi to 7 ft/day at 68 psi. Ignoring the points at loads below 1 psi, the change in the log value of the hydraulic conductivity was linear with the change in the log of the load applied. In general, the hydraulic conductivity for the carpet products was much lower than previously reported for TDA. For example, Finney et al. (2013) reported a hydraulic conductivity of 307 ft/day for TDA at 44 psi while in Experiment 3, a hydraulic conductivity of 16 ft/day was determined for shredded carpet at 40 psi. Finney et al. (2013) also reported that the hydraulic conductivity of TDA appeared to change with the applied hydraulic head, an unusual phenomenon not observed in the carpet material in this study.
Carpet Product Leachate Water Quality

To provide one measure of the potential impact that the leachate from the carpet product might have on any receiving water, a Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) analysis, each with their own constituent list (Table 4), was performed on a shredded carpet sample. Only a few of constituents (shown in bold in Table 4) were determined to have concentrations above the method detection limit (MDL). If the concentrations of any of the constituents tested exceed the solubility threshold limit concentrations (STLC), the tested material is classified as a hazardous waste. The concentrations of detected constituents in the shredded carpet WET and TCLP analysis were at least two orders of magnitude lower than the STLC (Table 5), therefore based on this criteria, the carpet would not be considered a hazardous waste.

<table>
<thead>
<tr>
<th>Test Procedure</th>
<th>Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WET test</strong></td>
<td><strong>Constituents</strong></td>
</tr>
<tr>
<td>Antimony</td>
<td>Lead</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Mercury</td>
</tr>
<tr>
<td>Barium</td>
<td>Molybdenum</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Nickel</td>
</tr>
<tr>
<td>Bromofluorobenzene</td>
<td>Selenium</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Silver</td>
</tr>
<tr>
<td>Chromium</td>
<td>Thallium</td>
</tr>
<tr>
<td>Chromium, hexavalent</td>
<td>Toluene-d8</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Trichloroethene</td>
</tr>
<tr>
<td>Copper</td>
<td>Vanadium</td>
</tr>
<tr>
<td>Dibromofluoromethane</td>
<td>Zinc</td>
</tr>
<tr>
<td><strong>Fluoride</strong></td>
<td></td>
</tr>
<tr>
<td><strong>TCLP test</strong></td>
<td><strong>Constituents</strong></td>
</tr>
<tr>
<td>Arsenic</td>
<td>DCAA</td>
</tr>
<tr>
<td>Barium</td>
<td>2,4,5-TP (Silvex)</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Carbon tetrachloride</td>
</tr>
<tr>
<td>Chromium</td>
<td>Chlorobenzene</td>
</tr>
<tr>
<td>Lead</td>
<td>Chloroform</td>
</tr>
<tr>
<td>Mercury</td>
<td>Benzene</td>
</tr>
<tr>
<td>Selenium</td>
<td>1,4-Dichlorobenzene</td>
</tr>
<tr>
<td>Silver</td>
<td>1,2-Dichloroethane</td>
</tr>
<tr>
<td>Endrin</td>
<td>1,1-Dichloroethene</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>Methyl ethyl ketone</td>
</tr>
<tr>
<td>Heptachlor epoxide</td>
<td>Tetrachloroethene</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>Trichloroethene</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>Vinyl chloride</td>
</tr>
<tr>
<td>Dibutylchlororinate</td>
<td>Bromofluorobenzene</td>
</tr>
<tr>
<td>gamma-BHC (Lindane)</td>
<td>Dibromofluoromethane</td>
</tr>
<tr>
<td>Chlordane (tech)</td>
<td>Toluene-d8</td>
</tr>
<tr>
<td>2,4-D</td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Constituents detected in the WET and TCLP analysis compared to the STLCs.

<table>
<thead>
<tr>
<th>Test</th>
<th>Constituent</th>
<th>Result (mg/l)</th>
<th>STLC&lt;sup&gt;a&lt;/sup&gt; (mg/l)</th>
<th>Above STLC?</th>
</tr>
</thead>
<tbody>
<tr>
<td>WET</td>
<td>Antimony</td>
<td>0.023</td>
<td>15</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Barium</td>
<td>0.45</td>
<td>100</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Chromium</td>
<td>0.066</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Cobalt</td>
<td>0.016</td>
<td>80</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td>0.14</td>
<td>25</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Fluoride</td>
<td>0.46</td>
<td>180</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>0.042</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Molybdenum</td>
<td>0.13</td>
<td>350</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Nickel</td>
<td>0.15</td>
<td>20</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Thallium</td>
<td>0.04</td>
<td>7</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td>3</td>
<td>250</td>
<td>No</td>
</tr>
<tr>
<td>TCLP</td>
<td>Barium</td>
<td>0.051</td>
<td>100</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Chromium</td>
<td>0.022</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>0.0092</td>
<td>5</td>
<td>No</td>
</tr>
</tbody>
</table>

[a] STLC values are calculated on the concentrations of the elements, not the compounds.

To further evaluate the potential impact that the leachate from a carpet product might have on a receiving water, leachate samples were collected from jars of shredded carpet, carpet fluff, and carpet underlayment soaking in distilled water. Samples were collected from jars where carpet, fluff, and underlayment had been soaking for one month. A sample was also collected from a jar where carpet had been soaking for two months. Finally, a sample was collected from a jar where carpet had soaked for two months, then drained and refilled with distilled water, and then allowed to soak for an additional month. Jars only containing distilled water were also sampled to serve as blanks.

All of the leachate samples were analyzed for a variety of water quality constituents, ranging from common organic and inorganic compounds to a wide assortment of volatile and semi-volatile compounds. The leachate from the shredded carpet that had been soaking two months and a blank were analyzed for the full list of constituents (Table 6). The remaining leachate samples were analyzed for a subset of the constituents that previous research suggested were most likely to be of concern for PET carpet products.

Results from the leachate experiment are presented as a per unit mass loading rate, with units of mg of constituent per kg of the carpet material, and as concentration with units of mass of constituent per liter of leachate. Since the density of carpet, underlayment, and fluff are different from one another, and the exact amount of material added to each glass jar differed, the unit mass loading rate provides a normalized comparison of the relative rate at which the materials leach compounds into water.
compared to one another. However, the concentrations of the constituents in the leachate may also be of interest as it might be considered a “worst case” scenario of a situation where the water saturating a carpet material fill is suddenly released into a receiving environment. The magnitude of the concentration compared to regulatory frameworks (Table 7) and regulatory standards (Table 8) provides a way to characterize the potential for a constituent leaching from PET carpet based materials to be a water quality concern. The regulatory standards used for comparison to the constituent concentrations in carpet product leachate serve only as a point of reference for these worst-case scenarios. The selected standards apply primarily to drinking water and are not necessarily representative of appropriate regulatory frameworks for typical recycled carpet product applications.
Table 6. Water quality constituents analyzed for carpet product leachate samples (items in bold detected above MDLs).

<table>
<thead>
<tr>
<th>Method</th>
<th>Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals by EPA 200 Series Methods</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>Lithium</td>
</tr>
<tr>
<td>Antimony</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Manganese</td>
</tr>
<tr>
<td>Barium</td>
<td>Mercury</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Nickel</td>
</tr>
<tr>
<td>Chromium</td>
<td>Selenium</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Silver</td>
</tr>
<tr>
<td>Copper</td>
<td>Sodium</td>
</tr>
<tr>
<td>Iron</td>
<td>Sulfur</td>
</tr>
<tr>
<td>Lead</td>
<td>Zinc</td>
</tr>
<tr>
<td>Conventional Chemistry Parameters by APHA/EPA methods</td>
<td></td>
</tr>
<tr>
<td>Ammonia as N (SM4500NH3C)</td>
<td>Odor (EPA 140.1)</td>
</tr>
<tr>
<td>Color (SM2120B)</td>
<td>Turbidity (SM2130B)</td>
</tr>
<tr>
<td>Chloride</td>
<td>Orthophosphate</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>Chloroethane</td>
</tr>
<tr>
<td>Anions by EPA Method 300.0</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
</tr>
<tr>
<td>Nitrate as N</td>
<td></td>
</tr>
<tr>
<td>VOCs by EPA Method 8260B</td>
<td></td>
</tr>
<tr>
<td>1,1,1,2-Tetrachloroethane</td>
<td>Chloroform</td>
</tr>
<tr>
<td>1,1,1,Trichloroethane</td>
<td>Chloroform</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>Chloromethane</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>cis-1,2-Dichloroethene</td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
<td>cis-1,3-Dichloropropene</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>Dibromochloromethane</td>
</tr>
<tr>
<td>1,1-Dichloropropene</td>
<td>Dibromomethane</td>
</tr>
<tr>
<td>1,2,3-Trichlorobenzene</td>
<td>Dichlorodifluoromethane</td>
</tr>
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<td>1,2,3-Trichloropropene</td>
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<td>1,2,4-Trichlorobenzene</td>
<td>Hexachlorobutadiene</td>
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<td>1,2,4-Trimethylbenzene</td>
<td>Isopropylbenzene</td>
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<tr>
<td>1,2-Dibromo-3-chloropropane</td>
<td>m,p-Xylene</td>
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<td>1,2-Dibromoethane (EDB)</td>
<td>Methyl ethyl ketone</td>
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<td>1,2-Dichlorobenzene</td>
<td>Methyl isobutyl ketone</td>
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<td>1,2-Dichloroethane</td>
<td>Methyl tert-butyl ether</td>
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<td>1,2-Dichloropropene</td>
<td>Methylene chloride</td>
</tr>
<tr>
<td>1,3,5-Trimethylbenzene</td>
<td>Naphthalene</td>
</tr>
<tr>
<td>1,3-Dichlorobenzene</td>
<td>n-Butylbenzene</td>
</tr>
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<td>1,3-Dichloropropene</td>
<td>n-Propylbenzene</td>
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<td>1,4-Dichlorobenzene</td>
<td>o-Xylene</td>
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<td>2,2-Dichloropropene</td>
<td>p-Isopropytoluene</td>
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<td>2-Chlorotoluene</td>
<td>sec-Butylbenzene</td>
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<tr>
<td>2-Hexanone</td>
<td>Styrene</td>
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<tr>
<td>Method</td>
<td>Constituents</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>4-Chlorotoluene</td>
<td>tert-Butylbenzene</td>
</tr>
<tr>
<td>Acetone</td>
<td>Tetrachloroethene</td>
</tr>
<tr>
<td>Benzene</td>
<td>Toluene</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>trans-1,2-Dichloroethene</td>
</tr>
<tr>
<td>Bromochloromethane</td>
<td>trans-1,3-Dichloropropene</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>Trichloroethene</td>
</tr>
<tr>
<td>Bromoform</td>
<td>Trichlorofluoromethane</td>
</tr>
<tr>
<td>Bromomethane</td>
<td>Trichlorotrifluoroethane</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>Vinyl acetate</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Vinyl chloride</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>Xylenes (total)</td>
</tr>
<tr>
<td>Semivolatile Organic Compounds by EPA Methods 625 SIM</td>
<td></td>
</tr>
<tr>
<td>2-Methylnaphthalene</td>
<td>Di(2-ethylhexyl) adipate</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>Di(2-ethylhexyl) phthalate</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>Dibenz (a,h) anthracene</td>
</tr>
<tr>
<td>Anthracene</td>
<td>Di-n-butyl phthalate</td>
</tr>
<tr>
<td>Benzo (a) anthracene</td>
<td>Fluoranthene</td>
</tr>
<tr>
<td>Benzo (a) pyrene</td>
<td>Fluorene</td>
</tr>
<tr>
<td>Benzo (b) fluoranthene</td>
<td>Indeno (1,2,3-cd) pyrene</td>
</tr>
<tr>
<td>Benzo (g,h,i) perylene</td>
<td>Naphthalene</td>
</tr>
<tr>
<td>Benzo (k) fluoranthene</td>
<td>Phenanthrene</td>
</tr>
<tr>
<td>Chrysene</td>
<td>Pyrene</td>
</tr>
<tr>
<td>Regulatory Framework</td>
<td>Agency</td>
</tr>
<tr>
<td>----------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>California Maximum Contaminant Level (CA MCL)</td>
<td>California Department of Public Health</td>
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<tr>
<td>Maximum Contaminant Level Goal (MCLG)</td>
<td>US EPA</td>
</tr>
<tr>
<td>Secondary Maximum Contaminant Level (Secondary MCL)</td>
<td>US EPA</td>
</tr>
<tr>
<td>Public Health Goal (PHG)</td>
<td>California Office of Environmental Health Hazard Assessment</td>
</tr>
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</table>
Table 8. Constituent limits for various water quality regulatory frameworks (adapted from Finney et al., 2016).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CA MCL (mg/L)</th>
<th>MCLG (mg/L)</th>
<th>MCL (mg/L)</th>
<th>Secondary MCL (mg/L)</th>
<th>PHG</th>
<th>Aquatic Life Freshwater Quality Maximums (mg/L)</th>
<th>RAL (mg/L)</th>
<th>MSGP Benchmark (mg/L)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acute</td>
<td>Chronic</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>1</td>
<td>0.05 to 0.2</td>
<td>0.6</td>
<td>.75</td>
<td>0.087</td>
<td>(T) 0.75 (pH 6.5-9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Cadmium</td>
<td>0.005</td>
<td>0.005</td>
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<td>0.00004</td>
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<td>0.0021</td>
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<td>230</td>
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<tr>
<td>Copper</td>
<td>1 (2nd)</td>
<td>1.3</td>
<td>1.3*</td>
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<td>1.3</td>
<td>(T) 0.014</td>
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<td>Fluoride</td>
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<td>2.0</td>
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<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.015</td>
<td>0</td>
<td>0.015*</td>
<td>0.0002</td>
<td>0.065</td>
<td>0.0025</td>
<td>0.003</td>
<td>(T) 0.082</td>
</tr>
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<td>Manganese</td>
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<td></td>
<td></td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Magnesium</td>
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<td></td>
</tr>
<tr>
<td>Mercury</td>
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<td>0.002</td>
<td>0.002</td>
<td>0.0012</td>
<td>0.0014</td>
<td>0.00077</td>
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<td>(T) 0.0014</td>
</tr>
<tr>
<td>Molybdenium</td>
<td>0.1</td>
<td></td>
<td></td>
<td>0.012</td>
<td>0.47</td>
<td>0.052</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate (as N)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>45</td>
<td>10</td>
<td></td>
<td>0.68</td>
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</tr>
<tr>
<td>Orthophosphate</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfate</td>
<td></td>
<td></td>
<td></td>
<td>250</td>
<td></td>
<td></td>
<td>250</td>
<td></td>
</tr>
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<td>Thallium</td>
<td>0.002</td>
<td>0.0005</td>
<td>0.002</td>
<td>0.0001</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
<td></td>
<td>5 (metal taste)</td>
<td>0.12</td>
<td>0.12</td>
<td>3</td>
<td>(T) 0.12</td>
</tr>
<tr>
<td>Color</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>5 NTU</td>
<td></td>
<td></td>
<td>5 NTU (&lt;1 NTU 95% of time)</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odor</td>
<td></td>
<td></td>
<td></td>
<td>3 T.O.N.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td>6.5-8.5</td>
<td></td>
<td></td>
<td>6.0-9.0</td>
<td></td>
</tr>
</tbody>
</table>

(T) = total recoverable  (*) = Treatment Technique Action Level
Only 22 of the 115 constituents examined were determined to have concentrations above the MDL (Table 9). The results listed for the carpet products represents the average of two samples each from the 1-month soak of carpet, the underlayment, and the fluff, and three samples from the 2-month carpet soak. The detected constituents were primarily metals, with none of the volatile or semi-volatile compounds found above the MDL. Approximately half (12 of 22) of the detected constituents were found at concentrations above one or more regulatory levels. While the metals concentrations were often above MCLs and the leachate would not be suitable as a source of potable water, the only primary MCL exceed was for antimony concentrations and the remainder were for secondary MCLs, MCL goals, or MSGPs (stormwater permits for industrial dischargers). Since the material that the shredded carpet, fluff, and underlayment were manufactured from was a recycled product, the source of the constituents in the leachate could be from either the carpet itself, or from contaminates introduced during the initial use of the carpet or subsequent handling during the recycling process.

There is considerable variability in the per-unit loading of the constituents across carpet, fluff and underlayment (Table 10). There does not appear to be a trend where one type of product consistently has a higher load of a constituent per unit mass of carpet product than the others. Comparing the carpet that soaked one month versus two months shows numerous cases were the shorter soak period resulted in a greater mass of the constituent being found in the leachate, a counter intuitive outcome.

Results from the soak, drain, and then re-soak experiment show that not all of the potential water quality contaminates would be readily rinsed away with an initial “flush” of water. In this experiment, shredded carpet was soaked for two months, and then the leachate gravity drained from the jar. The jar was then refilled with distilled water and allowed to soak again for a month. The drain and refill procedure reduced the per unit loading of the constituents by 28 to 100% (average of 76%). Several constituents that were initially over a regulatory level were below the level in the leachate from the final, 1 month soaking period (Table 11).
### Table 9. Carpet product leachate concentrations and unit loading results.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Sample</th>
<th>Result</th>
<th>Above regulated value?</th>
<th>mg constituent/kg carpet product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aluminum</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>0.11</td>
<td>yes, chronic aquatic</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>0.038</td>
<td>no</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>0.0935</td>
<td>no</td>
<td>5.31</td>
</tr>
<tr>
<td><strong>Antimony</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>0.0096</td>
<td>yes, MCL/PHG</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.0081</td>
<td>yes, MCL/PHG</td>
<td>0.074</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>0.13</td>
<td>yes, MCLG</td>
<td>4.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>0.0125</td>
<td>yes, MCLG</td>
<td>0.710</td>
</tr>
<tr>
<td><strong>Barium</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>0.0125</td>
<td>no</td>
<td>0.113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.0102</td>
<td>no</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>0.00885</td>
<td>no</td>
<td>0.336</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>0.0062</td>
<td>no</td>
<td>0.352</td>
</tr>
<tr>
<td><strong>Cadmium</strong></td>
<td>mg/L</td>
<td>C2</td>
<td>0.0111</td>
<td>yes, PHG</td>
<td>0.010</td>
</tr>
<tr>
<td><strong>Chromium</strong></td>
<td>mg/L</td>
<td>C2</td>
<td>0.015</td>
<td>no</td>
<td>0.137</td>
</tr>
<tr>
<td><strong>Cobalt</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>0.0035</td>
<td>-----</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.0027</td>
<td>-----</td>
<td>0.025</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td>mg/L</td>
<td>C2</td>
<td>0.058</td>
<td>yes, MSGP</td>
<td>0.530</td>
</tr>
<tr>
<td><strong>Iron</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>0.49</td>
<td>yes, 2nd MCL</td>
<td>4.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.55</td>
<td>no</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>0.0845</td>
<td>no</td>
<td>3.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>0.046</td>
<td>no</td>
<td>2.62</td>
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<tr>
<td><strong>Magnesium</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>5.4</td>
<td>yes, MSGP</td>
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<td>C2</td>
<td>4.2</td>
<td>yes, MSGP</td>
<td>38.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>0.93</td>
<td>yes, MSGP</td>
<td>35.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>0.9</td>
<td>yes, MSGP</td>
<td>51.1</td>
</tr>
<tr>
<td><strong>Manganese</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>0.036</td>
<td>no</td>
<td>0.326</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.049</td>
<td>no</td>
<td>0.451</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>0.00525</td>
<td>no</td>
<td>0.199</td>
</tr>
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<td>F</td>
<td>0.0057</td>
<td>no</td>
<td>0.324</td>
</tr>
<tr>
<td><strong>Mercury</strong></td>
<td>ug/L</td>
<td>C2</td>
<td>0.1</td>
<td>no</td>
<td>0.00092</td>
</tr>
<tr>
<td><strong>Nickel</strong></td>
<td>mg/L</td>
<td>C2</td>
<td>0.0016</td>
<td>yes, PHG</td>
<td>0.146</td>
</tr>
<tr>
<td><strong>Sodium</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>80</td>
<td>-----</td>
<td>725.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>270</td>
<td>-----</td>
<td>2467.</td>
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<td></td>
<td></td>
<td>U</td>
<td>19.5</td>
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<td>740.</td>
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<td></td>
<td>F</td>
<td>14</td>
<td>-----</td>
<td>735.</td>
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<tr>
<td><strong>Sulfur</strong></td>
<td>mg/L</td>
<td>C1</td>
<td>20</td>
<td>-----</td>
<td>181.</td>
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<tr>
<td></td>
<td></td>
<td>C2</td>
<td>86</td>
<td>-----</td>
<td>783.</td>
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<td></td>
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<td>U</td>
<td>6.15</td>
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<td>233.</td>
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<td></td>
<td></td>
<td>F</td>
<td>5.2</td>
<td>-----</td>
<td>295.</td>
</tr>
<tr>
<td><strong>Zinc</strong></td>
<td>mg/L</td>
<td>C2</td>
<td>0.46</td>
<td>yes, aquatic life/MSGP</td>
<td>4.20</td>
</tr>
<tr>
<td><strong>Ammonia as N</strong></td>
<td>mg/L</td>
<td>C2</td>
<td>29</td>
<td>yes, aquatic life</td>
<td>265.</td>
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<tr>
<td>(SM4500NH3C)</td>
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<td><strong>Color</strong></td>
<td></td>
<td>C</td>
<td>70</td>
<td>yes, 2nd MCL</td>
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<tr>
<td>(SM2120B)</td>
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<td>C2</td>
<td>92</td>
<td>yes, 2nd MCL</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>U</td>
<td>29</td>
<td>yes, 2nd MCL</td>
<td></td>
</tr>
<tr>
<td>Constituent</td>
<td>Units</td>
<td>Sample</td>
<td>Result</td>
<td>Above regulated value?</td>
<td>mg constituent/kg carpet product</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Odor (EPA 140.1)</td>
<td>T.O.N.</td>
<td>C1</td>
<td>&gt;8000</td>
<td>yes, 2nd MCL</td>
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<td></td>
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<td>&gt;8000</td>
<td>yes, 2nd MCL</td>
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</tr>
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<td></td>
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<td>4.45</td>
<td>yes, 2nd MCL</td>
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</tr>
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<td></td>
<td></td>
<td>F</td>
<td>21.1</td>
<td>yes, 2nd MCL</td>
<td></td>
</tr>
<tr>
<td>Turbidity (SM2130B)</td>
<td>NTU</td>
<td>C1</td>
<td>39</td>
<td>yes, 2nd MCL</td>
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</tr>
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<td></td>
<td></td>
<td>C2</td>
<td>47</td>
<td>yes, 2nd MCL</td>
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</tr>
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<td></td>
<td></td>
<td>U</td>
<td>0.43</td>
<td>no</td>
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<td></td>
<td></td>
<td>F</td>
<td>0.61</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>C1</td>
<td>14</td>
<td>no</td>
<td>127.</td>
</tr>
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<td></td>
<td></td>
<td>C2</td>
<td>32</td>
<td>no</td>
<td>295.</td>
</tr>
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<td></td>
<td></td>
<td>P</td>
<td>5.8</td>
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<td>220.</td>
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<td></td>
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<td>5.45</td>
<td>no</td>
<td>286.</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>mg/L</td>
<td>C2</td>
<td>0.098</td>
<td>no</td>
<td>0.900</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>mg/L</td>
<td>C2</td>
<td>18</td>
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<td>164.</td>
</tr>
</tbody>
</table>

[1] C1 = one-month soak carpet, C2 = two-month soak carpet, F = carpet fluff, U = underlayment
Table 10. Comparison of unit loading of detected constituents in carpet, underlayment, and fluff.

<table>
<thead>
<tr>
<th>Test/Method</th>
<th>Constituent</th>
<th>Carpet (1-month soak)</th>
<th>Carpet (2-month soak)</th>
<th>Carpet underlayment</th>
<th>Carpet fluff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals by EPA 200 Series Methods</td>
<td>Aluminum</td>
<td>1.00</td>
<td>ND</td>
<td>1.44</td>
<td>5.31</td>
</tr>
<tr>
<td></td>
<td>Antimony</td>
<td>0.087</td>
<td>0.0747</td>
<td>4.93</td>
<td>0.710</td>
</tr>
<tr>
<td></td>
<td>Barium</td>
<td>0.113</td>
<td>0.093</td>
<td>0.336</td>
<td>0.325</td>
</tr>
<tr>
<td></td>
<td>Cadmium</td>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chromium</td>
<td></td>
<td></td>
<td>0.137</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cobalt</td>
<td>0.032</td>
<td>0.025</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td></td>
<td></td>
<td>0.53</td>
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</tr>
<tr>
<td></td>
<td>Iron</td>
<td>4.44</td>
<td>5.00</td>
<td>3.21</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>Magnesium</td>
<td>48.9</td>
<td>38.7</td>
<td>35.3</td>
<td>51.1</td>
</tr>
<tr>
<td></td>
<td>Manganese</td>
<td>0.326</td>
<td>0.451</td>
<td>0.199</td>
<td>0.324</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
<td></td>
<td></td>
<td>0.00092</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nickel</td>
<td></td>
<td></td>
<td>0.146</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sodium</td>
<td>725.</td>
<td>2467.</td>
<td>740.</td>
<td>735.</td>
</tr>
<tr>
<td></td>
<td>Sulfur</td>
<td>181.</td>
<td>783.</td>
<td>233.</td>
<td>295.</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td></td>
<td></td>
<td>4.20</td>
<td></td>
</tr>
<tr>
<td>Conventional Chemistry Parameters by APHA/EPA methods</td>
<td>Ammonia as N (SM4500NH3C)</td>
<td></td>
<td></td>
<td>265</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Color (SM2120B)</td>
<td>[a] 70</td>
<td>[a] 91.7</td>
<td>[a] 29</td>
<td>[a] 14</td>
</tr>
<tr>
<td></td>
<td>Odor (EPA 140.1)</td>
<td>[b] &gt;8000</td>
<td>[b] &gt;8000</td>
<td>[b] 4.45</td>
<td>[b] 21.1</td>
</tr>
<tr>
<td></td>
<td>Turbidity (SM2130B)</td>
<td>[c] 39.5</td>
<td>[c] 46.73</td>
<td>[c] 0.43</td>
<td>[c] 0.61</td>
</tr>
<tr>
<td>Anions by EPA Method 300.0</td>
<td>Chloride</td>
<td>127.</td>
<td>295.</td>
<td>220.</td>
<td>286.</td>
</tr>
<tr>
<td></td>
<td>Nitrate as N</td>
<td></td>
<td></td>
<td>0.896</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orthophosphate</td>
<td></td>
<td></td>
<td>164.</td>
<td></td>
</tr>
</tbody>
</table>

Notes: [a] units of CU [b] units of TON [c] units of NTU
Table 11. Comparison of leachate quality after soak and drain cycle (items in bold exceed one or more regulatory limits in Table 8).

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Result Concentration</th>
<th>mg constituent/kg carpet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2-month soak</td>
<td>Following drain and 1-month soak</td>
</tr>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>0.11</td>
<td>0.073</td>
</tr>
<tr>
<td>Antimony</td>
<td>mg/L</td>
<td>0.0088</td>
<td>ND</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0.0111</td>
<td>0.0087</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.0011</td>
<td>ND</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.015</td>
<td>ND</td>
</tr>
<tr>
<td>Cobalt</td>
<td>mg/L</td>
<td>0.0030</td>
<td>ND</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.0324</td>
<td>0.004</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>0.524</td>
<td>0.24</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>4.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>0.0368</td>
<td>0.018</td>
</tr>
<tr>
<td>Mercury</td>
<td>ug/L</td>
<td>0.057</td>
<td>ND</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.0043</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>138.6</td>
<td>60</td>
</tr>
<tr>
<td>Sulfur</td>
<td>mg/L</td>
<td>49.5</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.46</td>
<td>0.015</td>
</tr>
<tr>
<td>Ammonia as N (SM4500NH3C)</td>
<td>mg/L</td>
<td>29</td>
<td>0.28</td>
</tr>
<tr>
<td>Color (SM2120B)</td>
<td>CU</td>
<td>83</td>
<td>17</td>
</tr>
<tr>
<td>Odor (EPA 140.1)</td>
<td>T.O.N.</td>
<td>&gt;8000</td>
<td>&gt;8000</td>
</tr>
<tr>
<td>Turbidity (SM2130B)</td>
<td>NTU</td>
<td>36.54</td>
<td>0.3</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>17.92</td>
<td>7.3</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>mg/L</td>
<td>0.081</td>
<td>0.044</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>mg/L</td>
<td>9.95</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Preliminary analysis was also made of the potential for leachate from the powdered carpet backing to affect the quality of a receiving water. Calcium (80%), magnesium (8%), aluminum (4%) and sodium (2%) accounted for nearly 95% of the dry weight mass of the compounds investigated (Table 12). The only organic compounds detected were Bis (2-ethylhexyl) phthalate, Butyl benzyl phthalate, and Di-n-butyl phthalate, all at mass fractions less than 0.01%. These compounds are often used as plastic softeners, and present in a wide variety of consumer products.

To investigate the mobilization of the soluble fraction of the various compounds in the backing powder, the powder was allowed to soak in distilled water with the pH adjusted to three different
values using HCl. In each case, sufficient powder was added to yield a solution exceeding 10,000 mg/l. After a week, the concentration of the compounds previously identified as contained in the backing powder were determined for the supernate (Table 13). In general, the concentrations increased with decreasing pH, likely resulting from the increased solubility of the calcium carbonate binder/filler in the powder as the pH decreases. However, even under these relatively extreme conditions, few of the constituent concentrations exceeded the drinking water MCLs or aquatic life freshwater quality maximums listed in Table 8. Only aluminum and manganese concentrations exceeded primary or secondary drinking water MCLs. Hydrochloric acid added to the two pH adjusted containers is believed responsible for the high chloride concentration in the samples collected from those containers. Direct discharge of the leachate might result in water quality impacts due to the concentrations of nitrogen compounds in all three containers, but the nitrogen could be a beneficial nutrient if the leachate was land applied. The concentration of magnesium and zinc exceeded the limit for the EPA stormwater mulit-sector general permit benchmark, but these metals are very reactive with soil and could be removed with soil mantel treatment.
Table 12. Dry mass fraction of constituents in powdered carpet backing.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Result (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>10000</td>
</tr>
<tr>
<td>Ammonia as NH3</td>
<td>6.8</td>
</tr>
<tr>
<td>Antimony</td>
<td>2.0</td>
</tr>
<tr>
<td>Barium</td>
<td>52</td>
</tr>
<tr>
<td>Benzoic acid</td>
<td>35</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl)phthalate</td>
<td>19</td>
</tr>
<tr>
<td>Boron</td>
<td>24</td>
</tr>
<tr>
<td>Butyl benzyl phthalate</td>
<td>9.0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.086</td>
</tr>
<tr>
<td>Calcium</td>
<td>220000</td>
</tr>
<tr>
<td>Chloride</td>
<td>3300</td>
</tr>
<tr>
<td>Chromium</td>
<td>2.0</td>
</tr>
<tr>
<td>Cobalt</td>
<td>1.0</td>
</tr>
<tr>
<td>Copper</td>
<td>6.3</td>
</tr>
<tr>
<td>Di-n-butyl phthalate</td>
<td>5.3</td>
</tr>
<tr>
<td>Fluoride</td>
<td>160</td>
</tr>
<tr>
<td>Iron</td>
<td>1600</td>
</tr>
<tr>
<td>Lead</td>
<td>1.3</td>
</tr>
<tr>
<td>Magnesium</td>
<td>23000</td>
</tr>
<tr>
<td>Manganese</td>
<td>76</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.045</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>1.5</td>
</tr>
<tr>
<td>Nickel</td>
<td>1.8</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>35</td>
</tr>
<tr>
<td>Nitrite as N</td>
<td>35</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>310</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>500</td>
</tr>
<tr>
<td>Potassium</td>
<td>810</td>
</tr>
<tr>
<td>Selenium</td>
<td>3.0</td>
</tr>
<tr>
<td>Silicon</td>
<td>240</td>
</tr>
<tr>
<td>Sodium</td>
<td>4700</td>
</tr>
<tr>
<td>Strontium</td>
<td>220</td>
</tr>
<tr>
<td>Titanium</td>
<td>30</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen</td>
<td>4000</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>4100</td>
</tr>
<tr>
<td>Vanadium</td>
<td>1.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>56</td>
</tr>
</tbody>
</table>
Table 13. Constituent concentrations for leachate from powdered carpet backing under three pH conditions.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>pH = 7.2</th>
<th>pH = 5.9</th>
<th>pH = 5.4</th>
<th>Standard exceeded (see Table 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 &amp; 4-Methylphenol</td>
<td>ug/L</td>
<td>6.4</td>
<td>ND</td>
<td>ND</td>
<td>---</td>
</tr>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>0.19</td>
<td>0.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&lt;sup&gt;a&lt;/sup&gt;US Secondary MCL, &lt;sup&gt;b&lt;/sup&gt;CA MCL</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>6.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.96</td>
<td>ND</td>
<td>&lt;sup&gt;c&lt;/sup&gt;Aquatic life chronic</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>0.0066</td>
<td>0.036</td>
<td>0.046</td>
<td>No</td>
</tr>
<tr>
<td>Benzoic acid</td>
<td>ug/L</td>
<td>ND</td>
<td>34</td>
<td>24</td>
<td>---</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl)phthalate</td>
<td>ug/L</td>
<td>3.3</td>
<td>4.6</td>
<td>8.0</td>
<td>---</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td>0.39</td>
<td>0.36</td>
<td>0.35</td>
<td>---</td>
</tr>
<tr>
<td>Butyl benzyl phthalate</td>
<td>ug/L</td>
<td>ND</td>
<td>2.0</td>
<td>3.4</td>
<td>---</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>14</td>
<td>650</td>
<td>830</td>
<td>---</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
<td>0.00035</td>
<td>ND</td>
<td>0.00063</td>
<td>No</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>25</td>
<td>1400*</td>
<td>2100*</td>
<td>*Cl from HCl addition</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>ND</td>
<td>ND</td>
<td>0.0043</td>
<td>No</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.029</td>
<td>0.034</td>
<td>0.053</td>
<td>No</td>
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<tr>
<td>Diethyl phthalate</td>
<td>ug/L</td>
<td>6.1</td>
<td>9.9</td>
<td>12</td>
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<tr>
<td>Di-n-butyl phthalate</td>
<td>ug/L</td>
<td>ND</td>
<td>3.4</td>
<td>4.6</td>
<td>---</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>0.15</td>
<td>0.42</td>
<td>0.50</td>
<td>No</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>0.37&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>&lt;sup&gt;d&lt;/sup&gt;US Secondary MCL</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>1.6&lt;sup&gt;e&lt;/sup&gt;</td>
<td>11&lt;sup&gt;e&lt;/sup&gt;</td>
<td>20&lt;sup&gt;e&lt;/sup&gt;</td>
<td>&lt;sup&gt;e&lt;/sup&gt;MSGP Benchmark</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>0.016</td>
<td>0.22&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.32&lt;sup&gt;f&lt;/sup&gt;</td>
<td>&lt;sup&gt;f&lt;/sup&gt;US Secondary MCL</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.00009</td>
<td>ND</td>
<td>0.00006</td>
<td>No</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>mg/L</td>
<td>0.0091</td>
<td>0.019</td>
<td>0.021</td>
<td>---</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>0.0037</td>
<td>0.0068</td>
<td>0.0068</td>
<td>No</td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>mg/L</td>
<td>2.5</td>
<td>4.6</td>
<td>5.1</td>
<td>---</td>
</tr>
<tr>
<td>Phenol</td>
<td>ug/L</td>
<td>ND</td>
<td>1.7</td>
<td>2.6</td>
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</tr>
<tr>
<td>Phosphorus</td>
<td>mg/L</td>
<td>1.8</td>
<td>2.8</td>
<td>3.2</td>
<td>---</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
<td>9.8</td>
<td>12</td>
<td>7.8</td>
<td>---</td>
</tr>
<tr>
<td>Silica</td>
<td>mg/L</td>
<td>2.7</td>
<td>3.8</td>
<td>5.5</td>
<td>---</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>65</td>
<td>82</td>
<td>82</td>
<td>---</td>
</tr>
<tr>
<td>Strontium</td>
<td>mg/L</td>
<td>0.053</td>
<td>0.74</td>
<td>0.95</td>
<td>---</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen</td>
<td>mg/L</td>
<td>17</td>
<td>12</td>
<td>13</td>
<td>---</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>mg/L</td>
<td>17</td>
<td>12</td>
<td>13</td>
<td>---</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.14&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0.36&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0.44&lt;sup&gt;g&lt;/sup&gt;</td>
<td>&lt;sup&gt;g&lt;/sup&gt;Aquatic life acute and MSGP Benchmark</td>
</tr>
</tbody>
</table>

<sup>a</sup>US Secondary MCL, <sup>b</sup>CA MCL, <sup>c</sup>Aquatic life chronic, <sup>d</sup>US Secondary MCL, <sup>e</sup>MSGP Benchmark, <sup>f</sup>US Secondary MCL, <sup>g</sup>Aquatic life acute and MSGP Benchmark.
Summary and Conclusions

The experiments conducted during this project have determined basic physical properties of shredded carpet, carpet fluff, and an underlayment pad, each manufactured from recycled PET carpet. Saturated shredded carpet and underlayment retain more than their weight of water after gravity draining, likely due to the extremely high surface area of the fibers in the product. The water adsorption of the carpet was over 200% compared to 131% for the underlayment, perhaps reflecting some loss of adsorption capacity of the underlayment due to the heat fusing of fibers in the top and bottom surface layer of the pad.

The density of the shredded carpet, fluff, and underlayment was determined to be 1.19 g/cm³, 0.52 g/cm³, and 1.01 g/cm³ respectively. The shredded carpet was expected to be the densest of the products due to the dense material used in the carpet backing (primarily calcium carbonate). The underlayment density is considerably higher than the parent fluff density. This result may be due to changes in the material that occur when the fluff is heat treated to form the underlayment, the presence of residual carpet backing in the underlayment, or experimental error.

The compressibility, porosity, hydraulic conductivity of shredded carpet and carpet fluff were determined for a range of vertical loading conditions. While the response to changes in loading is similar, carpet fluff tends to be more compressible and have a lower porosity compared to the shredded carpet. The fluff also tends to recover from a compressive load more quickly, but not as completely as does shredded carpet. However, addition testing at uniform loading is necessary to further investigate this behavior and to determine how the response of the materials may differ as a function of the length of time a load is applied. The two materials have nearly identical hydraulic conductivities under the same loading. Both materials are more compressible and have a much lower hydraulic conductivity than TDA under similar loading conditions.

A TCLP and WET analysis was performed on a shredded carpet sample. Only a few of constituents included in the analysis were determined to have concentrations above the MDL, and were at least two orders of magnitude lower than the STLC. Therefore based on these criteria, the carpet would not be considered a hazardous waste.

The potential impact that the leachate from a carpet product might have on a receiving water was evaluated using leachate samples from jars of shredded carpet, carpet fluff, and carpet underlayment soaking in distilled water. Samples were collected from jars where carpet, fluff, and underlayment had been soaking for one month and a sample was collected from a jar where carpet had been soaking for two months. Concentrations of the constituents are higher than would be expected in a field application.
since it unlikely that a fill of the material would be subject to an extended soaking and then have the leachate suddenly released into a receiving water. Only 22 of the 115 constituents examined were determined to have concentrations above the MDL. The detected constituents were primarily metals, and did not include any of the volatile or semi-volatile compounds examined. While approximately half of the detected constituents were found at concentrations above one or more regulatory levels, the only primary MCL exceed was for antimony concentrations and the remainder were for secondary MCLs, MCL goals, or MSGPs. Additional investigation is required to determine whether the source of the constituents in the leachate are from the carpet itself, or contaminates introduced during the initial use of the carpet or subsequent handling during the recycling process. The mass load of the constituents per unit mass of carpet, fluff, or underlayment suggests that the leachate of no one product is more likely to contribute to water quality impairment than the other products. While there was uncertainty about the role that soaking time has on constituent loss rate, the results did show that the unit loss rate (mg/kg of product) is reduced by an average of 76% following a first “flush” of leachate.

Preliminary analysis was also made of the potential for leachate from powdered carpet backing to affect the quality of a receiving water. Calcium, magnesium, aluminum and sodium accounted for nearly 95% of the dry weight mass of the compounds investigated. The remaining compounds were trace amounts of nutrients, metals, and phthalates. The soluble fraction of the various compounds in the carpet backing was determined after soaking the powder in distilled water with the pH adjusted to three different values using HCl. In general, the concentrations of the leachate constituents increased with decreasing pH, likely resulting from the increased solubility of the calcium carbonate binder/filler in the powder as the pH decreases. Few of the constituent concentrations exceeded the drinking water MCLs or aquatic life freshwater quality maximums. Direct discharge of the leachate might result in water quality impacts due to the concentrations of nitrogen compounds, magnesium and zinc, but those could be removed with soil mantel treatment.
References


## Appendix A

### List of All Constituents Tested - Liquid Samples

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Detection limit (DL)</th>
<th>Reporting limit (RL)</th>
<th>units</th>
<th>Detected?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals by EPA 200 Series Methods</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.02</td>
<td>0.05</td>
<td>mg/l</td>
<td>Y</td>
</tr>
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Note: **Unless otherwise stated, test performed by Alpha Analytical Laboratories**
# Appendix B

**List of All Constituents Tested - Dry Samples**

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<th>Constituent</th>
<th>Detection limit (DL)</th>
<th>Reporting limit (RL)</th>
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<th>Detected?</th>
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<td>4-Chloroaniline</td>
<td>4.0</td>
<td>13</td>
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<td>4-Chlorophenyl phenyl ether</td>
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<td>mg/kg</td>
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<td>Acenaphthene</td>
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<td>N</td>
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<td>0.40</td>
<td>1.2</td>
<td>mg/kg</td>
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<td>Constituent</td>
<td>Detection limit (DL)</td>
<td>Reporting limit (RL)</td>
<td>units</td>
<td>Detected?</td>
</tr>
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<tr>
<td>Anthracene</td>
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<td>1.2</td>
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<tr>
<td>Benzo (a) anthracene</td>
<td>0.40</td>
<td>6.6</td>
<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>Benzo (a) pyrene</td>
<td>0.60</td>
<td>1.2</td>
<td>mg/kg</td>
<td>N</td>
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<tr>
<td>Benzo (b) fluoranthene</td>
<td>0.60</td>
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<td>N</td>
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<tr>
<td>Benzo (g,h,i) perylene</td>
<td>0.60</td>
<td>1.2</td>
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<td>Benzoic acid</td>
<td>12</td>
<td>32</td>
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<td>Benzyl alcohol</td>
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<td>Bis(2-chloroethyl)ether</td>
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<td>mg/kg</td>
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<td>N</td>
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<td>Hexachlorocyclopentadiene</td>
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<td>N</td>
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<td>4.0</td>
<td>6.6</td>
<td>mg/kg</td>
<td>N</td>
</tr>
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<td>Indeno (1,2,3-cd) pyrene</td>
<td>0.40</td>
<td>1.2</td>
<td>mg/kg</td>
<td>N</td>
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<td>Isophorone</td>
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<td>mg/kg</td>
<td>N</td>
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<tr>
<td>Naphthalene</td>
<td>0.40</td>
<td>1.2</td>
<td>mg/kg</td>
<td>N</td>
</tr>
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<td>Nitrobenzene</td>
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<td>6.6</td>
<td>mg/kg</td>
<td>N</td>
</tr>
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<td>6.0</td>
<td>13</td>
<td>mg/kg</td>
<td>N</td>
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<tr>
<td>N-Nitrosodi-n-propylamine</td>
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<td>mg/kg</td>
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<td>Pentachlorophenol</td>
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<td>mg/kg</td>
<td>N</td>
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<td>Phenanthrene</td>
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<td>mg/kg</td>
<td>N</td>
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<td>Phenol</td>
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<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>Pyrene</td>
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<td>mg/kg</td>
<td>N</td>
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<td><strong>VOAs with EPA 8260B</strong></td>
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<tr>
<td>1,1,1,2-Tetrachloroethane</td>
<td>0.070</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>0.090</td>
<td>0.17</td>
<td>mg/kg</td>
<td>Y</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>0.080</td>
<td>0.17</td>
<td>mg/kg</td>
<td>Y</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
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<td>0.17</td>
<td>mg/kg</td>
<td>Y</td>
</tr>
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<td>1,1-Dichloroethane</td>
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<td>0.17</td>
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<td>1,1-Dichloroethene</td>
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<td>0.17</td>
<td>mg/kg</td>
<td>Y</td>
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<td>0.17</td>
<td>mg/kg</td>
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<td>1,2,3-Trichlorobenzene</td>
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<td>0.17</td>
<td>mg/kg</td>
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</tr>
<tr>
<td>1,2,3-Trichloropropane</td>
<td>0.070</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>Constituent</td>
<td>Detection limit (DL)</td>
<td>Reporting limit (RL)</td>
<td>units</td>
<td>Detected?</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------</td>
<td>----------------------</td>
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<td>1,2,4-Trichlorobenzene</td>
<td>0.080</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
</tr>
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<td>1,2,4-Trimethylbenzene</td>
<td>0.070</td>
<td>0.17</td>
<td>mg/kg</td>
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</tr>
<tr>
<td>1,2-Dibromo-3-chloropropane</td>
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<td>0.17</td>
<td>mg/kg</td>
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<td>1,2-Dibromomethane (EDB)</td>
<td>0.080</td>
<td>0.17</td>
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<td>N</td>
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<tr>
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<td>0.060</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<td>1,2-Dichloroethane</td>
<td>0.080</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
<td>0.060</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>1,3,5-Trimethylbenzene</td>
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<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<td>1,3-Dichlorobenzene</td>
<td>0.080</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<td>1,4-Dichlorobenzene</td>
<td>0.060</td>
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<td>mg/kg</td>
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<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<td>0.090</td>
<td>0.17</td>
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<td>N</td>
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<td>N</td>
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<td>0.70</td>
<td>mg/kg</td>
<td>N</td>
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<tr>
<td>Benzene</td>
<td>0.070</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>0.070</td>
<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<tr>
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<td>0.080</td>
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<td>N</td>
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<td>Bromodichloromethane</td>
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<td>mg/kg</td>
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<td>Bromomethane</td>
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<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<td>mg/kg</td>
<td>N</td>
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<tr>
<td>Chloromethane</td>
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<td>mg/kg</td>
<td>N</td>
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<td>N</td>
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<td>Methyl ethyl ketone</td>
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<td>Methyl isobutyl ketone</td>
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<td>mg/kg</td>
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<td>0.17</td>
<td>mg/kg</td>
<td>N</td>
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<td>Constituent</td>
<td>Detection limit (DL)</td>
<td>Reporting limit (RL)</td>
<td>units</td>
<td>Detected?</td>
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<td>mg/kg</td>
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<td>trans-1,3-Dichloropropene</td>
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<td>mg/kg</td>
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<tr>
<td>Fluoride</td>
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<td>5.0</td>
<td>mg/kg</td>
<td>Y</td>
</tr>
<tr>
<td>Nitrate as N</td>
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<td>10</td>
<td>mg/kg</td>
<td>Y</td>
</tr>
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<td>Total Nitrogen</td>
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<td>mg/kg</td>
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Note: ** Unless otherwise stated, test performed by Alpha Analytical Laboratories
TCLP Analysis Results
Enclosed are the results of analyses for samples received by the laboratory on 08/17/16 09:10. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeanette L. Poplin For David S. Pingatore
Project Manager
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Laboratory ID</th>
<th>Matrix</th>
<th>Date Sampled</th>
<th>Date Received</th>
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<td>Other (W)</td>
<td>08/16/16 11:00</td>
<td>08/17/16 09:10</td>
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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
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<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
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<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<td>mg/L</td>
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<td>EPA 6010B</td>
<td>U</td>
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<td><strong>Surrogates: Toluene-d8</strong></td>
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## PET Carpet

**16H1661-01(Other (W))**

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<th>Dilution</th>
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<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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**Surrogate: Dibutylphthalate**

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**TCLP Chlorinated Herbicides by EPA Method 8151A**

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<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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**Surrogate: DCAA**

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### TCLP Metals by EPA 6000/7000 Series Methods - Quality Control

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TCLP Metals by EPA 6000/7000 Series Methods - Quality Control

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Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata CA, 95521

Project Manager: Brad Finney
Project: Haz - Federal RCRA TCLP
Project Number: -
Reported: 09/06/16 14:06

**TCLP Volatile Organic Compounds by EPA Method 8260B - Quality Control**

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## TCLP Volatile Organic Compounds by EPA Method 8260B - Quality Control

### Batch AH64169 - ZHE GCMS

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<tr>
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<td>0.010</td>
<td>100</td>
<td>mg/L</td>
<td>0.0200</td>
<td>ND</td>
<td>100</td>
<td>70-130</td>
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<tr>
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<td>7.5</td>
<td>mg/L</td>
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<td>ND</td>
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<td>0.010</td>
<td>0.70</td>
<td>mg/L</td>
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<td>0.0258</td>
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<td>Surrogate: Toluene-d8</td>
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### TCLP Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AH64169 - ZHE GCMS**

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<th>Analyte</th>
<th>Result</th>
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<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>0.0200</td>
<td>0.010</td>
<td>0.50 mg/L</td>
<td>0.0200</td>
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<tr>
<td>Carbon tetrachloride</td>
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<td>96.8 70-130</td>
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<tr>
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<tr>
<td>Chloroform</td>
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<tr>
<td>1,4-Dichlorobenzene</td>
<td>0.0199</td>
<td>0.010</td>
<td>7.5 mg/L</td>
<td>0.0200</td>
<td>ND</td>
<td>99.7 70-130</td>
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<tr>
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<tr>
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<td>Methyl ethyl ketone</td>
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<tr>
<td>Tetrachloroethene</td>
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<td>J</td>
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<tr>
<td>Trichloroethene</td>
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<td>102 70-130</td>
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<tr>
<td>Vinyl chloride</td>
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<td>0.20 mg/L</td>
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<td>ND</td>
<td>90.8 70-130</td>
<td>0.768</td>
<td>25</td>
<td>J</td>
</tr>
<tr>
<td>Surrogate: Bromofluorobenzene</td>
<td>0.0250</td>
<td>mg/L</td>
<td>0.0250</td>
<td>100 70-130</td>
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<tr>
<td>Surrogate: Dibromofluoromethane</td>
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<td>0.0250</td>
<td>88.2 70-130</td>
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<tr>
<td>Surrogate: Toluene-d8</td>
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<td>mg/L</td>
<td>0.0250</td>
<td>96.2 70-130</td>
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</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
## TCLP Pesticides and PCBs by EPA Method 8081/8082 - Quality Control

### Batch AH63793 - EPA 1311 TCLP/3510B

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<th>Analyte</th>
<th>Result</th>
<th>Reporting MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>gamma-BHC (Lindane)</td>
<td>ND</td>
<td>0.00000080</td>
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<td>mg/L</td>
<td></td>
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<tr>
<td>Chlordane (tech)</td>
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<td>0.000020</td>
<td>0.030</td>
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<tr>
<td>Endrin</td>
<td>ND</td>
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<td>mg/L</td>
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<tr>
<td>Heptachlor</td>
<td>ND</td>
<td>0.0000010</td>
<td>0.0080</td>
<td>mg/L</td>
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<tr>
<td>Heptachlor epoxide</td>
<td>ND</td>
<td>0.0000020</td>
<td>0.0080</td>
<td>mg/L</td>
<td></td>
<td></td>
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<tr>
<td>Methoxychlor</td>
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<td>0.0000020</td>
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<td>mg/L</td>
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<tr>
<td>Toxaphene</td>
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<td>mg/L</td>
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<td>Surrogate: Dibutylchlorendate</td>
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### LCS (AH63793-BS1)

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<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>gamma-BHC (Lindane)</td>
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<tr>
<td>Heptachlor</td>
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<td>31-112</td>
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<tr>
<td>Heptachlor epoxide</td>
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<td>mg/L</td>
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<td>72-115</td>
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### LCS Dup (AH63793-BSD1)

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<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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<tbody>
<tr>
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<tr>
<td>Heptachlor</td>
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<td>0.0000010</td>
<td>0.0080</td>
<td>mg/L</td>
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<td>31-112</td>
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### TCLP Chlorinated Herbicides by EPA Method 8151A - Quality Control

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<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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<tr>
<td>2,4-D</td>
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<td>mg/L</td>
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<tr>
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<tr>
<td>2,4-D</td>
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<td>0.50</td>
<td>mg/L</td>
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<td>95.2</td>
<td>48-135</td>
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<tr>
<td>2,4,5-TP (Silvex)</td>
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<tr>
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</tr>
<tr>
<td>2,4-D</td>
<td>1.68</td>
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<td>mg/L</td>
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<td>87.5</td>
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<tr>
<td>2,4,5-TP (Silvex)</td>
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<tr>
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<td>mg/L</td>
<td>0.0142</td>
<td>94.5</td>
<td>54-124</td>
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</table>

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Notes and Definitions

<table>
<thead>
<tr>
<th>J</th>
<th>Detected but below the Reporting Limit; therefore, result is an estimated concentration, detected but not quantified (DNQ).</th>
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<tbody>
<tr>
<td>QM-04</td>
<td>High RPD and/or poor percent recovery may reflect sample non-homogeneity.</td>
</tr>
<tr>
<td>U</td>
<td>Analyte included in analysis, but not detected at or above MDL.</td>
</tr>
<tr>
<td>ND</td>
<td>Analyte NOT DETECTED at or above the reporting limit</td>
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<tr>
<td>dry</td>
<td>Sample results reported on a dry weight basis</td>
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<td>REC</td>
<td>Recovery</td>
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<tr>
<td>RPD</td>
<td>Relative Percent Difference</td>
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</table>
Work Order: 1608C89

Report Created for: Alpha Analytical Laboratories
208 Mason Street
Ukiah, CA 95482

Project Contact: David S. Pingatore
Project P.O.: 16H1661

Project Received: 08/26/2016

Analytical Report reviewed & approved for release on 08/31/2016 by:

Angela Rydelius,
Laboratory Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in the case narrative.
## Glossary of Terms & Qualifier Definitions

**Client:** Alpha Analytical Laboratories  
**Project:** 16H1661  
**WorkOrder:** 1608C89

### Glossary Abbreviation

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%D</td>
<td>Serial Dilution Percent Difference</td>
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<td>DLT</td>
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<td>DUP</td>
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<td>MB</td>
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<td>RRT</td>
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<td>WET (STLC)</td>
<td>Waste Extraction Test (Soluble Threshold Limit Concentration)</td>
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# Analytical Report

**Client:** Alpha Analytical Laboratories  
**Date Received:** 8/26/16 9:27  
**Date Prepared:** 8/29/16  
**Project:** 16H1661  
**WorkOrder:** 1608C89  
**Extraction Method:** SW1311/SW3510C  
**Analytical Method:** SW8270C  
**Unit:** mg/L

## Semi-Volatile Organics (TCLP)

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<td>1608C89-001A</td>
<td>Solid</td>
<td>08/16/2016 11:00</td>
<td>GC21</td>
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NELAP 4033ORELAP

Angela Rydelius, Lab Manager
## Analytical Report

**Client:** Alpha Analytical Laboratories  
**WorkOrder:** 1608C89  
**Extraction Method:** SW1311/SW3510C  
**Analytical Method:** SW8270C  
**Unit:** mg/L

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<td>Solid</td>
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# Analytical Report

**Client:** Alpha Analytical Laboratories  
**WorkOrder:** 1608C89  
**Date Received:** 8/26/16 9:27  
**Date Prepared:** 8/29/16  
**Project:** 16H1661  
**Extraction Method:** SW1311/SW3510C  
**Analytical Method:** SW8270C  
**Unit:** mg/L

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**Analyst(s):** REB

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NELAP 4033ORELAP

Angela Rydelius, Lab Manager
Quality Control Report

Client: Alpha Analytical Laboratories

WorkOrder: 1608C89

BatchID: 125856

Extraction Method: SW1311/SW3510C

Analytical Method: SW8270C

Unit: mg/L

Sample ID: MB/LCS-125856

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(Cont.)

NELAP 4033ORELAP

QA/QC Officer
## Quality Control Report

**Client:** Alpha Analytical Laboratories  
**WorkOrder:** 1608C89  
**Date Prepared:** 8/26/16  
**BatchID:** 125856  
**Date Analyzed:** 8/29/16  
**Extraction Method:** SW1311/SW3510C  
**Analytical Method:** SW8270C  
**Unit:** mg/L  
**Sample ID:** MB/LCS-125856  

### QC Summary Report for SW8270C (TCLP)

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Quality Control Report

Client: Alpha Analytical Laboratories
Date Prepared: 8/26/16
Date Analyzed: 8/29/16
Instrument: GC21
Matrix: Soil
Project: 16H1661

WorkOrder: 1608C89
BatchID: 125856
Extraction Method: SW1311/SW3510C
Analytical Method: SW8270C
Unit: mg/L
Sample ID: MB/LCS-125856

QC Summary Report for SW8270C (TCLP)

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**CHAIN-OF-CUSTODY RECORD**

**WorkOrder:** 1608C89  
**ClientCode:** ALPU  
**QuoteID:** 6409

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**Bill to:**  
Accounts Payable  
Alpha Analytical Laboratories  
208 Mason Street  
Ukiah, CA 95482

**Email:** sspeaks@alpha-labs.com; david@alpha-lab cc/3rd Party:

**Report to:**  
David S. Pingatore  
Alpha Analytical Laboratories  
208 Mason Street  
Ukiah, CA 95482

**Email:** sspeaks@alpha-labs.com; david@alpha-lab cc/3rd Party:

**Date Received:** 08/26/2016  
**Date Logged:** 08/26/2016  
**Requested TAT:** 3 days;

**Prepared by:** Alexandra Iniguez

**Comments:**

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days). Hazardous samples will be returned to client or disposed of at client expense.
WORK ORDER SUMMARY

Client Name: ALPHA ANALYTICAL LABORATORIES
Project: 16H1661
Comments:

QC Level: David S. Pingatore
Client Contact: sspeak@alpha-labs.com;david@alpha-labs.com; lquinn@alpha-labs.com
Contact's Email:

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</table>

NOTES: - STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).
- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.
SUBCONTRACT ORDER
Alpha Analytical Laboratories, Inc.

16H1661

SENDING LABORATORY:
Alpha Analytical Laboratories, Inc.
208 Mason St.
Ukiah, CA 95482
Phone: (707)468-0401
Fax: (707)468-5267
Project Manager: David S. Pingatore

RECEIVING LABORATORY:
McCgCampbell Analytical
1534 Willowpass Rd.
Pittsburg, CA 94565
Phone: (925) 252-9262
Fax: (925) 252-9269
Terms: Net 30

Analysis | Due | Expires | Comments
--- | --- | --- | ---
16H1661-01 PET Carpet [Other (W)] Sampled 08/16/16 11:00 Pacific

8270 RCRA Semivolatiles TCLP 08/31/16 12:00 08/30/16 11:00

Containers Supplied:
16 oz. jar (B)

☐ Report to State

System Name:  
User ID:  
System Number:  
Employed by:  
Sampler:  

Released By 8/25/16  
Received By 8/12/11 9:27

Released By  
Received By

Page 1 of 1
**Sample Receipt Checklist**

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<td>Date Logged: 8/26/2016</td>
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<td>Chain of custody present?</td>
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<td>Chain of custody signed when relinquished and received?</td>
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<td>Shipping container/cooler in good condition?</td>
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<td>Samples in proper containers/bottles?</td>
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<td>Sample containers intact?</td>
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<td>Sufficient sample volume for indicated test?</td>
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<td>All samples received within holding time?</td>
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<td>Sample/Temp Blank temperature</td>
<td>Temp: 4.1°C</td>
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<td>Water - VOA vials have zero headspace / no bubbles?</td>
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<td>pH acceptable upon receipt (Metal: &lt;2; 522: &lt;4; 218.7: &gt;8)?</td>
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<td><strong>Comments:</strong></td>
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# Chain of Custody - Work Order

Reports and invoices delivered by email in PDF format

Lab No: 164/1661

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<th>Invoice to (if different)</th>
<th>Project Information</th>
<th>Analysis Request</th>
<th>TAT</th>
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<td>Environmental Resources &amp; Engineering</td>
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<tr>
<td>1 Harpster Street, Arcata CA 95521</td>
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</tr>
<tr>
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<tr>
<td><a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
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Field Sampler - Printed Name & Signature: [Signature]

Sample Identification: PET Carpet 6/17/14 140

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<th>Container</th>
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Sample Notes or CDPH Source Numbers:

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</thead>
</table>

Relinquished by: [Signature]

Received by: [Signature]

Date: 8/17/14

CDPH Write On EDT Transmission? ○ Yes ● No

State System Number: [Number]

If "Y" please enter the Source Number(s) in the column above

CA Geotracker EDF Report? ○ Yes ● No

Global ID: [ID]

EDF ID (Email Address): [Email Address]
WET Analysis Results
Enclosed are the results of analyses for samples received by the laboratory on 08/17/16 09:10. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

[Signature]

Chelsea L. Sandelin For David S. Pingatore
Project Manager
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Laboratory ID</th>
<th>Matrix</th>
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<td>16H1659-01</td>
<td>Other (W)</td>
<td>08/16/16 11:00</td>
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### PET Carpet

**16H1659-01(Other (W))**

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<th>Batch</th>
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<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<td>08/31/16 15:37</td>
<td>EPA 6010B</td>
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<td>08/31/16 15:37</td>
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</table>

**DI WET Metals by EPA 6000/7000 Series Methods**

**DIWET Anions by EPA Method 300.0**

| Fluoride | 0.46 | 0.070 | 0.10 mg/L | 1 | AH64241 | 08/31/16 19:51 | 08/31/16 19:51 | EPA 300.0 |

**STLC Volatile Organics by EPA Method 8260B**

| Trichloroethene | ND | 0.00012 | 200 mg/L | 1 | AH64055 | 08/22/16 13:30 | 08/24/16 17:48 | EPA 8260B | U      |

Surrogates:
- Bromoform: 70-130 % Surrogate: Bromoform
- Dibromoform: 70-130 % Surrogate: Dibromoform
- Toluene-d8: 83.6 % Surrogate: Toluene-d8

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
# STLC Metals by EPA 6000/7000 Series Methods - Quality Control

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<td>0.0235</td>
<td>95.3</td>
<td>70-130</td>
<td>2.22</td>
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<tr>
<td>Arsenic</td>
<td>1.78</td>
<td>0.040</td>
<td>0.10</td>
<td>mg/L</td>
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<td>88.9</td>
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<td>0.050</td>
<td>mg/L</td>
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<td>ND</td>
<td>86.7</td>
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<td>Cadmium</td>
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<td>0.0160</td>
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<td>mg/L</td>
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<td>Lead</td>
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<td>mg/L</td>
<td>2.00</td>
<td>0.0421</td>
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<td>91.7</td>
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<td>Nickel</td>
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<td>0.151</td>
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<td>Selenium</td>
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<td>mg/L</td>
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<td>ND</td>
<td>88.0</td>
<td>70-130</td>
<td>3.16</td>
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<tr>
<td>Silver</td>
<td>1.81</td>
<td>0.30</td>
<td>0.50</td>
<td>mg/L</td>
<td>2.00</td>
<td>ND</td>
<td>90.7</td>
<td>70-130</td>
<td>3.31</td>
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<tr>
<td>Thallium</td>
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<td>0.10</td>
<td>mg/L</td>
<td>2.00</td>
<td>0.0395</td>
<td>89.1</td>
<td>70-130</td>
<td>2.43</td>
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<td>Vanadium</td>
<td>1.77</td>
<td>0.0060</td>
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<td>mg/L</td>
<td>2.00</td>
<td>ND</td>
<td>88.6</td>
<td>70-130</td>
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<td>Zinc</td>
<td>4.54</td>
<td>0.0080</td>
<td>0.50</td>
<td>mg/L</td>
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<td>2.99</td>
<td>77.6</td>
<td>70-130</td>
<td>2.81</td>
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</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### DI WET Metals by EPA 600/7000 Series Methods - Quality Control

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>Source</th>
<th>%REC</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Batch AH64223 - DIWET/7196A</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Blank (AH64223-BLK1)</td>
<td>ND</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium, hexavalent</td>
<td>0.0050</td>
<td></td>
<td>0.010 mg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCS (AH64223-B51)</td>
<td>0.0947</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>0.100</td>
<td>94.7</td>
<td>80-120</td>
</tr>
<tr>
<td>Chromium, hexavalent</td>
<td>0.0947</td>
<td></td>
<td>0.010 mg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCS Dup (AH64223-BSD1)</td>
<td>0.0947</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>0.100</td>
<td>94.7</td>
<td>80-120</td>
</tr>
<tr>
<td>Chromium, hexavalent</td>
<td>0.0947</td>
<td></td>
<td>0.010 mg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duplicate (AH64223-DUP1)</td>
<td>Source: 16H1659-01</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>0.100</td>
<td>94.7</td>
<td>80-120</td>
</tr>
<tr>
<td>Chromium, hexavalent</td>
<td>ND</td>
<td></td>
<td>0.010 mg/L</td>
<td></td>
<td>20 U</td>
</tr>
<tr>
<td>Matrix Spike (AH64223-MS1)</td>
<td>Source: 16H1659-01</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>0.100</td>
<td>80.9</td>
<td>0-200</td>
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<td>Chromium, hexavalent</td>
<td>0.0809</td>
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<td>0.010 mg/L</td>
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<tr>
<td>Matrix Spike Dup (AH64223-MSD1)</td>
<td>Source: 16H1659-01</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>0.100</td>
<td>81.9</td>
<td>0-200</td>
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<tr>
<td>Chromium, hexavalent</td>
<td>0.0819</td>
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<td>0.010 mg/L</td>
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<td>1.31</td>
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</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### DIWET Anions by EPA Method 300.0 - Quality Control

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<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>%REC</th>
<th>Limits</th>
<th>RPD</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Batch AH64241 - General Preparation</strong></td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blank (AH64241-BLK1)</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>Fluoride</td>
<td>ND</td>
<td>0.070</td>
<td>0.10 mg/L</td>
<td>U</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCS (AH64241-BS1)</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>Fluoride</td>
<td>5.03</td>
<td>0.070</td>
<td>0.10 mg/L</td>
<td>5.00</td>
<td>101</td>
<td>90-110</td>
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<td></td>
</tr>
<tr>
<td>Duplicate (AH64241-DUP1)</td>
<td>Source: 16H1886-01</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>Fluoride</td>
<td>ND</td>
<td>0.070</td>
<td>0.10 mg/L</td>
<td>ND</td>
<td>20</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td>Matrix Spike (AH64241-MS1)</td>
<td>Source: 16H1886-01</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>Fluoride</td>
<td>4.76</td>
<td>0.35</td>
<td>0.50 mg/L</td>
<td>5.00</td>
<td>ND</td>
<td>95.2</td>
<td>80-120</td>
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<tr>
<td>Matrix Spike Dup (AH64241-MSD1)</td>
<td>Source: 16H1886-01</td>
<td>Prepared &amp; Analyzed: 08/31/16</td>
<td>Fluoride</td>
<td>4.79</td>
<td>0.35</td>
<td>0.50 mg/L</td>
<td>5.00</td>
<td>ND</td>
<td>95.8</td>
<td>80-120</td>
</tr>
</tbody>
</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Notes and Definitions

J  Detected but below the Reporting Limit; therefore, result is an estimated concentration, detected but not quantified (DNQ).

U  Analyte included in analysis, but not detected at or above MDL.

ND  Analyte NOT DETECTED at or above the reporting limit

dry  Sample results reported on a dry weight basis

REC  Recovery

RPD  Relative Percent Difference
September 6, 2016

Alpha Analytical Laboratories, Inc.
208 Mason St.
Ukiah, CA 95482

Enclosed please find the results for the one aqueous sample received on August 30, 2016. This sample was analyzed for 2,3,7,8-TCDD by EPA method 8290A. Routine turn-around time was provided for this work.

This work was authorized under Alpha Analytical Laboratories’ project # 16H1659.

The “H” qualifier on the samples signifies that the percent recovery for an internal standard is below the method limits. The results were deemed acceptable due to the signal to noise for the internal standard chromatograph peaks being >10:1 and the detection limits calculated off of the internal standard were below the method lower calibration limit.

The report consists of a Cover Letter, Sample Inventory (Section I), Data Summary (Section II), Sample Tracking (Section VI), and Qualifiers/Abbreviations (Section VII). Raw Data (Section III), Continuing Calibration (Section IV), and Initial Calibration (Section V) are available in a full report (.pdf format) upon request.

If you have any questions regarding this report, please feel free to contact me at (916)932-5011.

Sincerely,

James M. Hedin
Director of Operations/CEO
jhedin@ceres-lab.com
<table>
<thead>
<tr>
<th>Ceres Sample ID:</th>
<th>Sample ID</th>
<th>Date Received</th>
<th>Collection Date &amp; Time</th>
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<tbody>
<tr>
<td>11111-001</td>
<td>16H1659-01 PET Carpet</td>
<td>8/30/2016</td>
<td>8/16/2016 11:00</td>
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</table>
Section II: Data Summary
# EPA Method 8290A

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Conc. (pg/L)</th>
<th>Qualifiers</th>
<th>Labeled Standards</th>
<th>% R</th>
<th>LCL-UCL (a)</th>
<th>Qualifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,3,7,8-TCDD</td>
<td>DL = 1.87</td>
<td></td>
<td>13C-2378-TCDD</td>
<td>82.9</td>
<td>40-135</td>
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<tr>
<td><strong>CRS</strong></td>
<td></td>
<td><strong>CRS</strong></td>
<td>37Cl4-2378-TCDD</td>
<td>88.5</td>
<td>40-135</td>
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</tbody>
</table>

- DL - Signifies Non-Detect (ND) at sample specific detection limit.
- EMPC - Estimated Maximum Possible Concentration due to ion abundance ratio failure.
- (a) - Lower control limit - Upper control limit

---

**Analyst:** JMH

**Reviewed by:** BS
### EPA Method 8290A

<table>
<thead>
<tr>
<th>Quality Assurance Sample</th>
<th>Laboratory Control Samples</th>
<th>QC Batch #:</th>
<th>Aqueous</th>
<th>Date Extracted:</th>
<th>9/1/2016</th>
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<tbody>
<tr>
<td>Project ID:</td>
<td>16H1659</td>
<td></td>
<td>LCS</td>
<td>1491</td>
<td>Sample Size:</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Analyte</th>
<th>%Rec.</th>
<th>% Rec.</th>
<th>%RSD</th>
<th>Labeled Standards</th>
<th>LCS % Rec.</th>
<th>LCS Dup % Rec.</th>
<th>Limits (a)</th>
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<td>88.9</td>
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<td>84.5</td>
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<td>CRS</td>
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<tr>
<td>37Cl4-2378-TCDD</td>
<td>84.1</td>
<td>83.4</td>
<td>40-135</td>
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</tbody>
</table>

(a) Limits based on method acceptance criteria.

---

Analyst: JMH

Reviewed by: BS
**EPA Method 8290A**

<table>
<thead>
<tr>
<th>Client Sample ID: 16H1659-01 PET Carpet</th>
<th>Ceres Sample ID: 11111-001</th>
<th>QC Batch #: 1491</th>
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<tr>
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<td>Date Collected: 8/16/2016</td>
<td>Sample Size: 1.029 L</td>
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<tr>
<td>Date Extracted: 9/2/2016</td>
<td>Time Collected: 11:00 AM</td>
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</tr>
<tr>
<td>Date Received: 8/30/2016</td>
<td>ZB-5MS Analysis: 9/2/2016</td>
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<tr>
<td>Date Extracted: 8/16/2016</td>
<td>Date Collected: 8/16/2016</td>
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</tr>
<tr>
<td>Time Collected: 11:00 AM</td>
<td>Sample Size: 1.029 L</td>
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<table>
<thead>
<tr>
<th>Analyte</th>
<th>Conc. (pg/L)</th>
<th>Qualifiers</th>
<th>Labeled Standards</th>
<th>% R</th>
<th>LCL-UCL (a)</th>
<th>Qualifiers</th>
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<tbody>
<tr>
<td>2,3,7,8-TCDD</td>
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<td>40-135</td>
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</table>

**CRS**

<table>
<thead>
<tr>
<th>Labeled Standards</th>
<th>% R</th>
<th>LCL-UCL (a)</th>
<th>Qualifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>37Cl4-2378-TCDD</td>
<td>87.7</td>
<td>40-135</td>
<td></td>
</tr>
</tbody>
</table>

**DL** - Signifies Non-Detect (ND) at sample specific detection limit.

**EMPC** - Estimated Maximum Possible Concentration due to ion abundance ratio failure.

(a) - Lower control limit - Upper control limit
Section VI: Sample Tracking
SUBCONTRACT ORDER
Alpha Analytical Laboratories, Inc.
16H1659

SENDING LABORATORY:
Alpha Analytical Laboratories, Inc.
208 Mason St.
Ukiah, CA 95482
Phone: (707) 468-0401
Fax: (707) 468-5267
Project Manager: David S. Pingatore

RECEIVING LABORATORY:
Ceres Labs
4919 Windplay Dr.
El Dorado Hills, CA 95762
Phone: (916) 932-5011
Fax: (916) 932-5017
Terms: Net 30

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Due</th>
<th>Expires</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>16H1659-01 PET Carpet [Other (W)] Sampled 08/16/16 11:00 Pacific</td>
<td>08/31/16 12:00</td>
<td>09/15/16 11:00</td>
<td></td>
</tr>
</tbody>
</table>

Dioxin 2378 TCDD 8290 STLC

Containers Supplied:
1L Amber- Unpres. (B)

☐ Report to State

System Name: ___________________________  Employed by: ___________________________
User ID: ___________________________  Sampler: ___________________________
System Number: ___________________________

Released By ___________________________ Date 8-25-16  Received By ___________________________ Date 8-30-16
## Sample Receipt Check List

<table>
<thead>
<tr>
<th>Ceres ID:</th>
<th>11111</th>
<th>Date/Time:</th>
<th>8/30/14</th>
<th>9:30</th>
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</thead>
<tbody>
<tr>
<td>Client Project ID:</td>
<td>Lot4 LoS1</td>
<td>Received Temp:</td>
<td>0.4°C</td>
<td>Acceptable:</td>
</tr>
<tr>
<td>Chain of Custody Relinquished by signed?</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Custody Seals?</td>
<td>Present?</td>
<td>Y/N</td>
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<tr>
<td></td>
<td>Intact?</td>
<td>Y/N</td>
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<td>NA:</td>
<td>NA</td>
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<tr>
<td>Unlabeled / Illegible Samples</td>
<td>Y/N</td>
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<td>Proper Containers:</td>
<td>Y/N</td>
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<tr>
<td>Preservation Acceptable (Chemical or Temperature)?</td>
<td>Y/N</td>
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<td></td>
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<tr>
<td>Drinking Water, Sodium Thiosulfate present?</td>
<td>Y/N</td>
<td>NA</td>
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</tr>
<tr>
<td>Aqueous sample pH:</td>
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<tr>
<td>List COC discrepancies:</td>
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<tr>
<td>List Damaged Samples:</td>
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</tr>
</tbody>
</table>

**Rev 6**
Form A5.0
Effective Date: 6/28/15
Section VII: Qualifiers/Abbreviations

J  Concentration found below the lower quantitation limit but greater than zero.
B  Analyte present in the associated Method Blank.
E  Concentration found exceeds the Calibration range of the HRGC/HRMS.
D  This analyte concentration was calculated from a dilution.
X  The concentration found is the estimated maximum possible concentration due to chlorinated diphenyl ethers present in the sample.
H  Recovery limits exceeded. See cover letter.
*  Results taken from dilution.
I  Interference. See cover letter.
Conc.  Concentration Found
DL  Calculated Detection Limit
ND  Non-Detect
% Rec.  Percent Recovery
Analytical Report

WorkOrder: 1608C92

Report Created for: Alpha Analytical Laboratories

208 Mason Street
Ukiah, CA 95482

Project Contact: David S. Pingatore
Project P.O.: 16H1659
Project Name: 16H1659
Project Received: 08/26/2016

Analytical Report reviewed & approved for release on 08/31/2016 by:

Angela Rydelius,
Laboratory Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in the case narrative.
# Glossary of Terms & Qualifier Definitions

**Client:** Alpha Analytical Laboratories  
**Project:** 16H1659  
**WorkOrder:** 1608C92

## Glossary Abbreviation

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>%D</td>
<td>Serial Dilution Percent Difference</td>
</tr>
<tr>
<td>95% Interval</td>
<td>95% Confident Interval</td>
</tr>
<tr>
<td>DF</td>
<td>Dilution Factor</td>
</tr>
<tr>
<td>DI WET</td>
<td>(DISTLC) Waste Extraction Test using DI water</td>
</tr>
<tr>
<td>DISS</td>
<td>Dissolved (direct analysis of 0.45 µm filtered and acidified water sample)</td>
</tr>
<tr>
<td>DLT</td>
<td>Dilution Test (Serial Dilution)</td>
</tr>
<tr>
<td>DUP</td>
<td>Duplicate</td>
</tr>
<tr>
<td>EDL</td>
<td>Estimated Detection Limit</td>
</tr>
<tr>
<td>ITEF</td>
<td>International Toxicity Equivalence Factor</td>
</tr>
<tr>
<td>LCS</td>
<td>Laboratory Control Sample</td>
</tr>
<tr>
<td>MB</td>
<td>Method Blank</td>
</tr>
<tr>
<td>MB % Rec</td>
<td>% Recovery of Surrogate in Method Blank, if applicable</td>
</tr>
<tr>
<td>MDL</td>
<td>Method Detection Limit</td>
</tr>
<tr>
<td>ML</td>
<td>Minimum Level of Quantitation</td>
</tr>
<tr>
<td>MS</td>
<td>Matrix Spike</td>
</tr>
<tr>
<td>MSD</td>
<td>Matrix Spike Duplicate</td>
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<tr>
<td>N/A</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>ND</td>
<td>Not detected at or above the indicated MDL or RL</td>
</tr>
<tr>
<td>NR</td>
<td>Data Not Reported due to matrix interference or insufficient sample amount.</td>
</tr>
<tr>
<td>PDS</td>
<td>Post Digestion Spike</td>
</tr>
<tr>
<td>PDS D</td>
<td>Post Digestion Spike Duplicate</td>
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<tr>
<td>PF</td>
<td>Prep Factor</td>
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<tr>
<td>RD</td>
<td>Relative Difference</td>
</tr>
<tr>
<td>RL</td>
<td>Reporting Limit (The RL is the lowest calibration standard in a multipoint calibration.)</td>
</tr>
<tr>
<td>RPD</td>
<td>Relative Percent Deviation</td>
</tr>
<tr>
<td>RRT</td>
<td>Relative Retention Time</td>
</tr>
<tr>
<td>SPK Val</td>
<td>Spike Value</td>
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<td>SPK Ref Val</td>
<td>Spike Reference Value</td>
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<tr>
<td>SPLP</td>
<td>Synthetic Precipitation Leachate Procedure</td>
</tr>
<tr>
<td>ST</td>
<td>Sorbent Tube</td>
</tr>
<tr>
<td>TCLP</td>
<td>Toxicity Characteristic Leachate Procedure</td>
</tr>
<tr>
<td>TEQ</td>
<td>Toxicity Equivalents</td>
</tr>
<tr>
<td>WET (STLC)</td>
<td>Waste Extraction Test (Soluble Threshold Limit Concentration)</td>
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</table>
Glossary of Terms & Qualifier Definitions

Client: Alpha Analytical Laboratories
Project: 16H1659
WorkOrder: 1608C92

Analytical Qualifiers

S  Surrogate spike recovery outside accepted recovery limits
a3  sample diluted due to high organic content.
a4  reporting limits raised due to the sample's matrix prohibiting a full volume extraction.
a14 reporting limit raised due to the physical nature of the sample
c2  surrogate recovery outside of the control limits due to matrix interference.

Quality Control Qualifiers

F2  LCS/LCSD recovery and/or RPD is out of acceptance criteria.
F3  the surrogate standard recovery and/or RPD is outside of acceptance limits.
**Organochlorine Pesticides & PCBs (STLC)**

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<thead>
<tr>
<th>Client ID</th>
<th>Lab ID</th>
<th>Matrix</th>
<th>Date Collected</th>
<th>Instrument</th>
<th>Batch ID</th>
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<td>1608C92-001A</td>
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<th>Result</th>
<th>MDL</th>
<th>RL</th>
<th>DF</th>
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<th>Surrogates</th>
<th>REC (%)</th>
<th>Limits</th>
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<td>Decachlorobiphenyl</td>
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<td>70-130</td>
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**Analytical Comments:** a14

**NELAP 4033ORELAP**

Angela Rydelius, Lab Manager
## Analytical Report

**Client:** Alpha Analytical Laboratories  
**Date Received:** 8/26/16 9:27  
**Date Prepared:** 8/29/16  
**Project:** 16H1659  
**Work Order:** 1608C92  
**Extraction Method:** CA Title 22/SW3510  
**Analytical Method:** SW8151A  
**Unit:** mg/L

### Chlorinated Herbicides by GC-ECD (STLC)

<table>
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<tr>
<th>Client ID</th>
<th>Lab ID</th>
<th>Matrix</th>
<th>Date Collected</th>
<th>Instrument</th>
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<th>DF</th>
<th>Date Analyzed</th>
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<td>Acifluorfen</td>
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<td>Dalapon</td>
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<td>Dicamba</td>
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<th>REC (%)</th>
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**Analyst(s):** DP

**Signatures:**

- **Angela Rydelius, Lab Manager**
## Phenols (STLC)

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<th>Lab ID</th>
<th>Matrix</th>
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### Analytes

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<th>MDL</th>
<th>RL</th>
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### Surrogates

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### Analytical Comments: a3,a4,c2

**Analysis:**

- **Client:** Alpha Analytical Laboratories
- **Date Received:** 8/26/16 9:27
- **Date Prepared:** 8/29/16
- **Project:** 16H1659
- **Work Order:** 1608C92
- **Extraction Method:** CA Title 22/SW3510C
- **Analytical Method:** SW8270C
- **Unit:** mg/L

**Data Collection:**

- **Client ID:** 16H1659-01
- **Lab ID:** 1608C92-001A
- **Matrix:** Solid
- **Date Collected:** 08/16/2016 11:00
- **Instrument:** GC21
- **Batch ID:** 125857

**Results:**

- **4-Chloro-3-methylphenol:** ND
- **2-Chlorophenol:** ND
- **2,4-Dichlorophenol:** ND
- **2,6-Dichlorophenol:** ND
- **2,4-Dimethylphenol:** ND
- **4,6-Dinitro-2-methylphenol:** ND
- **2,4-Dinitrophenol:** ND
- **2-Methylphenol (o-Cresol):** ND
- **3 & 4-Methylphenol (m,p-Cresol):** ND
- **2-Nitrophenol:** ND
- **4-Nitrophenol:** ND
- **Pentachlorophenol:** ND
- **Phenol:** ND
- **2,4,5-Trichlorophenol:** ND
- **2,4,6-Trichlorophenol:** ND

**Surrogates:**

- **2-Fluorophenol:** 105, 30-130
- **Phenol-d5:** 114, 30-130
- **Nitrobenzene-d5:** 100, 30-130
- **2-Fluorobiphenyl:** 117, 30-130
- **2,4,6-Tribromophenol:** 162, S
- **4-Terphenyl-d14:** 168, S

**Analyst:** REB

**Lab Manager:** Angela Rydelius

NELAP 4033ORELAP
Quality Control Report

Client: Alpha Analytical Laboratories
Date Prepared: 8/29/16
Date Analyzed: 8/30/16
Instrument: GC20
Matrix: Soil
Project: 16H1659

QC Summary Report for SW8081A (STLC)

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<th>MDL</th>
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Surrogate Recovery

| Decachlorobiphenyl | 0.00130 | 0.00134 | 0.0012 | 104     | 107     | 70-130 |

NELAP 4033ORELAP
QA/QC Officer
**Quality Control Report**

Client: Alpha Analytical Laboratories  
Date Prepared: 8/29/16  
Date Analyzed: 8/30/16  
Instrument: GC15A  
Matrix: Soil  
Project: 16H1659  

**QC Summary Report for SW8151A (STLC)**

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**Surrogate Recovery**

| DCAA     | 0.0861 | 0.0918 | 0.10 | 86   | 92   | 60-140 |

**WorkOrder:** 1608C92  
**BatchID:** 125850  
**Extraction Method:** CA Title 22/SW3510  
**Analytical Method:** SW8151A  
**Unit:** mg/L  
**Sample ID:** MB/LCS-125850
QC Summary Report for SW8270C (STLC)

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Surrogate Recovery

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<th>MDL</th>
<th>RL</th>
<th>SPK Val</th>
<th>MB SS %REC</th>
<th>LCS %REC</th>
<th>LCS Limits</th>
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<tr>
<td>2-Fluorophenol</td>
<td>0.0233</td>
<td>0.0214</td>
<td>0.020</td>
<td>117</td>
<td>107</td>
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<tr>
<td>Phenol-d5</td>
<td>0.0248</td>
<td>0.0230</td>
<td>0.020</td>
<td>124,F3</td>
<td>115,F2</td>
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<td>Nitrobenzene-d5</td>
<td>0.0205</td>
<td>0.0217</td>
<td>0.020</td>
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<td>109</td>
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<tr>
<td>2-Fluorobiphenyl</td>
<td>0.0197</td>
<td>0.0207</td>
<td>0.020</td>
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<td>108</td>
<td>1-160</td>
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<tr>
<td>2,4,6-Tribromophenol</td>
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<td>0.0216</td>
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<td>4-Terphenyl-d14</td>
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<td>111</td>
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<td>Client ID</td>
<td>Matrix</td>
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<td>Hold</td>
<td>Requested Tests (See legend below)</td>
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<tr>
<td>1608C92-001</td>
<td>16H1659-01</td>
<td>Solid</td>
<td>8/16/2016 11:00</td>
<td>A</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
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**Test Legend:**

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<tr>
<th>1</th>
<th>8081PCB_STLC_S</th>
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<tr>
<td>2</td>
<td>8151_STLC_S</td>
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<tr>
<td>3</td>
<td>8270_PHE_STLC_S</td>
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</table>

**Requested TAT:** 3 days;

**Date Received:** 08/26/2016

**Date Logged:** 08/26/2016

**Comments:**

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days). Hazardous samples will be returned to client or disposed of at client expense.

Prepared by: Alexandra Iniguez
## WORK ORDER SUMMARY

<table>
<thead>
<tr>
<th>Client Name:</th>
<th>ALPHA ANALYTICAL LABORATORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project:</td>
<td>16H1659</td>
</tr>
<tr>
<td>Comments:</td>
<td></td>
</tr>
<tr>
<td>QC Level:</td>
<td></td>
</tr>
<tr>
<td>Client Contact:</td>
<td>David S. Pingatore</td>
</tr>
<tr>
<td>Contact's Email:</td>
<td><a href="mailto:sspeaks@alpha-labs.com">sspeaks@alpha-labs.com</a>;<a href="mailto:david@alpha-labs.com">david@alpha-labs.com</a>; <a href="mailto:lquinn@alpha-labs.com">lquinn@alpha-labs.com</a></td>
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<td>Work Order:</td>
<td>1608C92</td>
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<tr>
<td>Date Logged:</td>
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### Work Order Summary Table

<table>
<thead>
<tr>
<th>Lab ID</th>
<th>Client ID</th>
<th>Matrix</th>
<th>Test Name</th>
<th>Containers /Composites</th>
<th>Bottle &amp; Preservative</th>
<th>De-chlorinated</th>
<th>Collection Date &amp; Time</th>
<th>TAT</th>
<th>Sediment Content</th>
<th>Hold</th>
<th>SubOut</th>
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<tbody>
<tr>
<td>1608C92-001A</td>
<td>16H1659-01</td>
<td>Solid</td>
<td>SW8270C (Phenols) (STLC)</td>
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<td>16OZ GJ</td>
<td></td>
<td>8/16/2016 11:00</td>
<td>3 days*</td>
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<td></td>
<td></td>
<td></td>
<td>SW8151A (Chlorinated Herbicides) (STLC)</td>
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<td></td>
<td>SW8081A (OC Pesticides &amp; PCBs) (STLC)</td>
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<td></td>
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</tbody>
</table>

### NOTES:

- STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).
- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.
SUBCONTRACT ORDER
Alpha Analytical Laboratories, Inc.
16H1659

SENDING LABORATORY:
Alpha Analytical Laboratories, Inc.
208 Mason St.
Ukiah, CA 95482
Phone: (707) 468-0401
Fax: (707) 468-5267
Project Manager: David S. Pingatore

RECEIVING LABORATORY:
McCabe Analytical
1534 Willowpass Rd.
Pittsburg, CA 94565
Phone: (925) 252-9262
Fax: (925) 252-9269
Terms: Net 30

Analysis | Due | Expires | Comments
--- | --- | --- | ---
16H1659-01 PET Carpet [Other (W)] Sampled 08/16/16 11:00 Pacific

8270 PCP STLC | 08/31/16 12:00 | 08/30/16 11:00 |
8151 STLC Herbs 1000x | 08/31/16 12:00 | 08/30/16 11:00 |
8081/8082 CAM Pesticides STLC | 08/31/16 12:00 | 08/30/16 11:00 |

Containers Supplied:
16 oz. jar (D) 16 oz. jar (E) 16 oz. jar (F)

☐ Report to State

System Name: [Signature]
Employed by: [Signature]
User ID: [Signature]
Sampler: [Signature]
System Number: [Signature]

Released By: [Signature] 8-25-16 3126116 09-27

Received By: [Signature]
Sample Receipt Checklist

Client Name:  Alpha Analytical Laboratories
Project Name:  16H1659
WorkOrder No:  1608C32  Matrix: Solids
Carrier:  OnTrac

Date and Time Received:  8/26/2016 09:27
Date Logged:  8/26/2016
Received by:  Alexandra Iniguez
Logged by:  Alexandra Iniguez

Chain of Custody (COC) Information

- Chain of custody present?  Yes ☑  No ☐
- Chain of custody signed when relinquished and received?  Yes ☑  No ☐
- Chain of custody agrees with sample labels?  Yes ☑  No ☐
- Sample IDs noted by Client on COC?  Yes ☑  No ☐
- Date and Time of collection noted by Client on COC?  Yes ☑  No ☐
- Sampler's name noted on COC?  Yes ☑  No ☐

Sample Receipt Information

- Custody seals intact on shipping container/cooler?  Yes ☑  No ☐  NA ☐
- Shipping container/cooler in good condition?  Yes ☑  No ☐
- Samples in proper containers/bottles?  Yes ☑  No ☐
- Sample containers intact?  Yes ☑  No ☐
- Sufficient sample volume for indicated test?  Yes ☑  No ☐

Sample Preservation and Hold Time (HT) Information

- All samples received within holding time?  Yes ☑  No ☐
- Sample/Temp Blank temperature  Temp: 4.1°C
- Water - VOA vials have zero headspace / no bubbles?  Yes ☑  No ☐  NA ✓
- Sample labels checked for correct preservation?  Yes ☑  No ☐
- pH acceptable upon receipt (Metal: <2; 522: <4; 218.7: >8)?  Yes ☑  No ☐  NA ✓
- Samples Received on Ice?  Yes ☑  No ☐
  (Ice Type: WET ICE )

UCMR3 Samples:
- Total Chlorine tested and acceptable upon receipt for EPA 522?  Yes ☑  No ☐  NA ✓
- Free Chlorine tested and acceptable upon receipt for EPA 218.7, 300.1, 537, 539?  Yes ☑  No ☐  NA ✓

Comments:
**Report to:** Humboldt State University

**Contact:** Brad Finney

**Address:** Environmental Resources & Engineering
1 Harst Street, Arcata CA 95521

**Phone/Fax:** 707-926-3918

**Email Address:** brad.finney@humboldt.edu

---

**Sample Identification**

**Sample Name:** PET Carpet

**Date:** 8/16/16

**Time:** 11:00

**Container**

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Qty</th>
<th>Preservative</th>
<th>Matrix</th>
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<td>1</td>
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<td>Soil</td>
</tr>
<tr>
<td>RPM 9275</td>
<td>1</td>
<td>None</td>
<td>Sand</td>
</tr>
<tr>
<td>RPM 9275</td>
<td>1</td>
<td>None</td>
<td>Silt</td>
</tr>
<tr>
<td>RPM 9275</td>
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<td>None</td>
<td>Other</td>
</tr>
<tr>
<td>RPM 9275</td>
<td>1</td>
<td>None</td>
<td>Water</td>
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</tbody>
</table>

---

**Relinquished by**

**Received by**

| UPS Ground via AAL acct # 894250 |

**Date:** 8-17-16

**Time:** 8:00

---

**Analysis Request**

**Project ID:** Haz - CAM STLC

**Project No.:**

**PO Number:**

**Total Number of Containers per Sample ID:**

**Extractions:** DI WET / STLC / ZHE / STLC

**Sample Notes or CDPH Source Numbers:**

---

**Field Sampler - Printed Name & Signature:**

Brad Finney

---

**Sample Name:** PET Carpet

**Date:** 8/16/16

**Time:** 11:00

**Relinquished by**

**Received by**

| UPS Ground via AAL acct # 894250 |

**Date:** 8-17-16

**Time:** 8:00

---

**CDPH Write On EDT Transmission?**

*Yes* ☑

**State System Number:**

**If "Y" please enter the Source Number(s) in the column above**

---

**CA Geotracker EDF Report?**

*Yes* ☑

---

**Global ID:**

**EDT to (Email Address):**

**Sampling Company Log Code:**

**Travel and Site Time:**

**Duration:**

**Acc. Supplier:**
Carpet - 1 month soak results
Enclosed are the results of analyses for samples received by the laboratory on 08/11/16 09:50. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeanette L. Poplin For David S. Pingatore
Project Manager
# Analytical Report for Samples

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Laboratory ID</th>
<th>Matrix</th>
<th>Date Sampled</th>
<th>Date Received</th>
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<tbody>
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<td>C1</td>
<td>16H1178-01</td>
<td>Water</td>
<td>08/10/16 10:00</td>
<td>08/11/16 09:50</td>
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<td>C2</td>
<td>16H1178-02</td>
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</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata CA, 95521

### Project Manager: Brad Finney

| Project: Special Leachate Project | Project Number: - | Reported: 08/26/16 15:24 |

---

| C1  | 16H1178-01(Water) |

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<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
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<td>Barium</td>
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<td>mg/L</td>
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<td>Cadmium</td>
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### Volatile Organic Compounds by EPA Method 8260B

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### Volatile Organic Compounds by EPA Method 8260B

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</table>

**Surrogate:**
- Dibromo-fluoromethane: 78.2% 46-130 ug/L
- Toluene-d8: 87.1% 59-132 ug/L
- Bromofluorobenzene: 105% 81-135 ug/L

### Additional Semivolatile Organic Compounds by EPA Method 625

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**Surrogate:**
- 2-Fluorobiphenyl: 79.1% 42-115 ug/L
- Nitrobenzene-d5: 93.2% 50-110 ug/L
- p-Terphenyl-d14: 123% 61-134 ug/L

### Semivolatile Organic Compounds by EPA Method 625 SIM

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### C1

**16H1178-01(Water)**

| Analyte          | Result | MDL | Limit | Units | Dilution | Batch         | Prepared       | Analyzed        | Method         | Notes |
|------------------|--------|-----|-------|-------|----------|---------------|----------------|----------------|----------------|----------------|-------|
| 2-Methylnaphthalene | ND     | 0.040 | 1.0 ug/L | 1     | AH64036  | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM     | U              |      |
| Naphthalene      | ND     | 0.040 | 0.20 ug/L | 1     | AH64036  | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM     | U              |      |
| Phenanthrene     | ND     | 0.030 | 0.20 ug/L | 1     | AH64036  | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM     | U              |      |
| Pyrene           | ND     | 0.030 | 0.20 ug/L | 1     | AH64036  | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM     | U              |      |
| Surrogate: 2-Fluorobiphenyl | 59.6 % | 34-133 | AH64036 | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM |
| Surrogate: Nitrobenzene-d5 | 59.0 % | 36-131 | AH64036 | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM |
| Surrogate: p-Terphenyl-d14 | 106 % | 35-156 | AH64036 | 08/15/16 08:00 | 08/25/16 19:18 | EPA 625SIM |

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
C2

16H1178-02(Water)

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Surrogate: Dibromofluoromethane

SURROGATE: 46-130
87.4 % 46-130
AH63964 08/22/16 15:00 08/22/16 23:32 | EPA 8260B

Surrogate: Toluene-d8

SURROGATE: 59-132
86.8 % 59-132
AH63964 08/22/16 15:00 08/22/16 23:32 | EPA 8260B

Surrogate: Bromofluorobenzene

SURROGATE: 81-135
103 % 81-135
AH63964 08/22/16 15:00 08/22/16 23:32 | EPA 8260B

Additional Semivolatile Organic Compounds by EPA Method 625

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Surrogate: 2-Fluorobiphenyl

SURROGATE: 16-195
87.0 % 42-115
AH63625 08/15/16 08:00 08/23/16 11:36 | EPA 625

Surrogate: Nitrobenzene-d5

SURROGATE: 56-110
83.5 % 56-110
AH63625 08/15/16 08:00 08/23/16 11:36 | EPA 625

Surrogate: p-Terphenyl-d14

SURROGATE: 61-134
108 % 61-134
AH63625 08/15/16 08:00 08/23/16 11:36 | EPA 625
### Metals by EPA 200 Series Methods

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### Conventional Chemistry Parameters by APHA/EPA Methods

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA, 95521

**Special Leachate Project**

**Reported:** 08/26/16 15:24

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**16H1178-03 (Water)**

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### Volatile Organic Compounds by EPA Method 8260B

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<th>Analyte</th>
<th>Result</th>
<th>MDL Limit</th>
<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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### Additional Semivolatile Organic Compounds by EPA Method 625

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C4

16H1178-04(Water)

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### Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA 95521

**Project Manager:** Brad Finney
**Project:** Special Leachate Project
**Reported Number:** 08/26/16 15:24

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### Reporting

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#### Anions by EPA Method 300.0

- **Chloride**
  - **Result:** 0.15
  - **MDL:** 0.10
  - **Limit:** 0.50 mg/L
  - **Units:** mg/L
  - **Batch:** Ah63578
  - **Prepared:** 08/12/16 21:05
  - **Analyzed:** 08/12/16 21:05
  - **Method:** EPA 300.0
  - **Notes:** J

- **Nitrate as N**
  - **Result:** 0.064
  - **MDL:** 0.40
  - **Limit:** 0.20 mg/L
  - **Units:** mg/L
  - **Batch:** Ah63598
  - **Prepared:** 08/12/16 09:50
  - **Analyzed:** 08/12/16 09:50
  - **Method:** EPA 300.0
  - **Notes:** J

- **Orthophosphate**
  - **Result:** 1.9
  - **MDL:** 0.70
  - **Limit:** 0.30 mg/L
  - **Units:** mg/L
  - **Batch:** Ah63598
  - **Prepared:** 08/12/16 09:50
  - **Analyzed:** 08/12/16 09:50
  - **Method:** EPA 300.0

#### Volatile Organic Compounds by EPA Method 8260B

- **Acetone**
  - **Result:** ND
  - **MDL:** 0.90
  - **Limit:** 5.0 ug/L
  - **Units:** ug/L
  - **Batch:** Ah63964
  - **Prepared:** 08/22/16 15:00
  - **Analyzed:** 08/23/16 00:42
  - **Method:** EPA 8260B
  - **Notes:** U

- **Benzene**
  - **Result:** ND
  - **MDL:** 0.30
  - **Limit:** 0.30 ug/L
  - **Units:** ug/L
  - **Batch:** Ah63964
  - **Prepared:** 08/22/16 15:00
  - **Analyzed:** 08/23/16 00:42
  - **Method:** EPA 8260B

- **Bromobenzene**
  - **Result:** ND
  - **MDL:** 0.40
  - **Limit:** 0.50 ug/L
  - **Units:** ug/L
  - **Batch:** Ah63964
  - **Prepared:** 08/22/16 15:00
  - **Analyzed:** 08/23/16 00:42
  - **Method:** EPA 8260B

### Notes

*The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.*
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### Volatile Organic Compounds by EPA Method 8260B

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### Additional Semivolatile Organic Compounds by EPA Method 625

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<th>Method</th>
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### Semivolatile Organic Compounds by EPA Method 625 SIM

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<th>Analyzed</th>
<th>Method</th>
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<tr>
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<tr>
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<tr>
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<td>EPA 625SIM</td>
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*The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.*
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**Conventional Chemistry Parameters by APHA/EPA Methods**

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**Volatile Organic Compounds by EPA Method 8260B**

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### Volatile Organic Compounds by EPA Method 8260B

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**Surrogates:**
- Dibromofluoromethane: 78.1% 46-130 AH63964 08/22/16 15:00 08/23/16 01:16 EPA 8260B
- Toluene-d8: 86.6% 59-132 AH63964 08/22/16 15:00 08/23/16 01:16 EPA 8260B
- Bromofluorobenzene: 105% 81-135 AH63964 08/22/16 15:00 08/23/16 01:16 EPA 8260B

### Additional Semivolatile Organic Compounds by EPA Method 625

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<th>Method</th>
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**Surrogates:**
- 2-Fluorobiphenyl: 79.0% 42-115 AH63625 08/15/16 08:00 08/23/16 13:29 EPA 625
- Nitrobenzene-d5: 76.5% 50-110 AH63625 08/15/16 08:00 08/23/16 13:29 EPA 625
- p-Terphenyl-d14: 92.0% 61-134 AH63625 08/15/16 08:00 08/23/16 13:29 EPA 625

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Humboldt State Univ - Env. Resources & Engineering  
1 Harpst Street  
Arcata, CA, 95521

Project Manager: Brad Finney  
Project: Special Leachate Project  
Reported: 08/26/16 15:24

C6  
16H1178-06(Water)

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Conventional Chemistry Parameters by APHA/EPA Methods

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Anions by EPA Method 300.0

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Volatile Organic Compounds by EPA Method 8260B

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## Results

### Volatile Organic Compounds by EPA Method 8260B

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<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
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**Surrogate:**
- Dibromofluoromethane: 77.4%, 46-130, AH63964
- Toluene-d8: 86.4%, 59-132, AH63964
- Bromofluorobenzene: 104%, 81-135, AH63964

### Additional Semivolatile Organic Compounds by EPA Method 625

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**Surrogate:**
- 2-Fluorobiphenyl: 88.5%, 42-115, AH63625
- Nitrobenzene-d5: 81.5%, 56-110, AH63625
- p-Terphenyl-d14: 110%, 61-134, AH63625

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</table>

**Surrogate:** Dibromofluoromethane 78.8% 46-130
Surrogate: Toluene-d8 86.9% 59-132
Surrogate: Bromofluorobenzene 104% 81-135

**Additional Semivolatile Organic Compounds by EPA Method 625**

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<tr>
<th>Analyte</th>
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<th>Units</th>
<th>Dilution</th>
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<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<td>Di(2-ethylhexyl) adipate</td>
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<td>08/24/16 11:12</td>
<td>EPA 625</td>
<td>J</td>
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</tbody>
</table>

**Surrogate:** 2-Fluorobiphenyl 81.2% 42-115
Surrogate: Nitrobenzene-d5 77.4% 50-110
Surrogate: p-Terphenyl-d14 116% 61-134

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### Result MDL

<table>
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<th>Date</th>
<th>Time</th>
<th>Sample ID</th>
<th>Result</th>
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<tbody>
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**Results for Metals by EPA 200 Series Methods**

- **Aluminum**: 0.039 mg/L
- **Antimony**: 0.15 mg/L
- **Barium**: 0.0096 mg/L
- **Cobalt**: 0.020 mg/L
- **Iron**: 0.069 mg/L
- **Magnesium**: 1.0 mg/L
- **Manganese**: 0.0055 mg/L
- **Sodium**: 20 mg/L

**Conventional Chemistry Parameters by APHA/EPA Methods**

- **Color**: 40
- **Odor**: 7.1
- **Turbidity**: 0.50

**Anions by EPA Method 300.0**

<table>
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<th>Result</th>
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**Volatile Organic Compounds by EPA Method 8260B**

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<th>Prepared</th>
<th>Analyzed</th>
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### Volatile Organic Compounds by EPA Method 8260B

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<th>Units</th>
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<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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### Additional Semivolatile Organic Compounds by EPA Method 625

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### Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA 95521

### Project Manager:
Brad Finney

### Project:
Special Leachate Project

### Project Number:
-  

### Reported:
08/26/16 15:24

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**C9**

#### 16H1178-09(Water)

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**Surrogate: Dibromofluoromethane**

- 77.7 % 46-130 AH63964 08/22/16 15:00 08/23/16 03:33 EPA 8260B

**Surrogate: Toluene-d8**

- 85.8 % 59-132 AH63964 08/22/16 15:00 08/23/16 03:33 EPA 8260B

**Surrogate: Bromofluorobenzene**

- 103 % 81-135 AH63964 08/22/16 15:00 08/23/16 03:33 EPA 8260B

#### Additional Semivolatile Organic Compounds by EPA Method 625

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Analyte | Result | Reporting Limit | Units | Dilution | Batch | Prepared | Analyzed | Method | Notes
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4-Chlorotoluene | ND | 3.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Dibromochloromethane | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,2-Dibromo-3-chloropropane | ND | 6.0 | 20 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
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Dibromomethane | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,2-Dichlorobenzene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,3-Dichlorobenzene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,4-Dichlorobenzene | ND | 3.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Dichlorodifluoromethane | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,1-Dichloroethane | ND | 5.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,2-Dichloroethane | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,1-Dichloroethene | ND | 3.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
cis-1,2-Dichloroethene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
trans-1,2-Dichloroethene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,2-Dichloropropane | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,3-Dichloropropane | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
2,2-Dichloropropane | ND | 5.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
1,1-Dichloropropene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
cis-1,3-Dichloropropene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
trans-1,3-Dichloropropene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
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2-Hexanone | ND | 4.0 | 50 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Hexachlorobutadiene | ND | 5.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Isopropylbenzene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
p-Isopropyltoluene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Methyl ethyl ketone | ND | 7.0 | 10 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Methyl isobutyl ketone | ND | 6.0 | 10 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Methyl tert-butyl ether | ND | 5.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Methylene chloride | ND | 5.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Naphthalene | ND | 5.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
n-Propylbenzene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U
Styrene | ND | 4.0 | 5.0 ug/L | 10 | AH63964 | 08/22/16 15:00 | 08/23/16 04:07 | EPA 8260B | U

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<th>MDL</th>
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<th>Batch</th>
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<th>Analyzed</th>
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**Metals by EPA 200 Series Methods**

**Conventional Chemistry Parameters by APHA/EPA Methods**

**Color**

18 3.0 5.0 CU 1 AH63173 08/12/16 08:00 08/12/16 08:00 SM2120B OD-3, T-2

**Odor**

2.2 1.0 T.O.N. 1 AH63173 08/11/16 16:30 08/11/16 16:30 EPA 140.1

**Turbidity**

0.64 0.050 0.10 NTU 1 AH63638 08/11/16 16:00 08/11/16 17:00 SM2130B

**Anions by EPA Method 300.0**

**Chloride**

5.5 0.50 2.5 mg/L 5 AH63578 08/13/16 00:04 08/13/16 00:04 EPA 300.0

**Volatile Organic Compounds by EPA Method 8260B**

**Acetone**

ND 9.0 50 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Benzene**

ND 3.0 3.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Bromobenzene**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Bromochloromethane**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Bromodichloromethane**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Bromomethane**

ND 3.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Bromomethane**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**n-Butylbenzene**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**sec-Butylbenzene**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**tert-Butylbenzene**

ND 3.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Carbon disulfide**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Carbon tetrachloride**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Chlorobenzene**

ND 3.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Chloroethane**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Chloroform**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**Chloromethane**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

**2-Chlorotoluene**

ND 4.0 5.0 ug/L 10 AH63964 08/22/16 15:00 08/23/16 04:42 EPA 8260B U

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### Volatile Organic Compounds by EPA Method 8260B

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<th>Limit</th>
<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
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### Additional Semivolatil Organic Compounds by EPA Method 625

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### Metals by EPA 200 Series Methods - Quality Control

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### Metals by EPA 200 Series Methods - Quality Control

#### Batch AH63833 - Metals Digest

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#### Matrix Spike Dup (AH63833-MSD1)

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#### Batch AH63834 - Metals Digest

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## Results

### Metals by EPA 200 Series Methods - Quality Control

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Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

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### Anions by EPA Method 300.0 - Quality Control

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Anions by EPA Method 300.0 - Quality Control

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Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA, 95521

Project Manager: Brad Finney
Project: Special Leachate Project
Project Number: -
Reported: 08/26/16 15:24

Volatile Organic Compounds by EPA Method 8260B - Quality Control

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Surrogate: Dibromofluoromethane 19.1 ug/L 25.0 76.2 46-130

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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AH63964 - VOAs in Water GCMS**

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**Volatile Organic Compounds by EPA Method 8260B - Quality Control**

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## Volatile Organic Compounds by EPA Method 8260B - Quality Control

### Batch AH63964 - VOAs in Water GCMS

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<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>Result</th>
<th>%REC Limits</th>
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### LCS Dup (AH63964-BSD1)

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Volatile Organic Compounds by EPA Method 8260B - Quality Control

Batch AH63964 - VOAs in Water GCMS

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<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
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<th>%REC Limits</th>
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## Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AH63964 - VOAs in Water GCMS**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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<tr>
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**Matrix Spike (AH63964-MS1)**

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**Batch AH63964 - VOAs in Water GCMS**

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<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC</th>
<th>%REC Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AH63964 - VOAs in Water GCMS**

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<th>%REC Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
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### Additional Semivolatile Organic Compounds by EPA Method 625 - Quality Control

#### Batch AH63625 - SVOAs in Water GCMS

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<th>Source Result</th>
<th>%REC Limits</th>
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### Additional Semivolatile Organic Compounds by EPA Method 625 - Quality Control

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<th>RPD</th>
<th>RPD Limit</th>
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### Batch AH63625 - SVOAs in Water GCMS

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<td>5.0 ug/L</td>
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<td>40.0</td>
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### Batch AH63679 - SVOAs in Water GCMS

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#### LCS Dup (AH63679-BSD1)

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### Additional Semivolatile Organic Compounds by EPA Method 625 - Quality Control

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<th>%REC Limits</th>
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**Matrix Spike Dup (AH63679-MSD1)**

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**Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control**

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### Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control

#### Batch AH64036 - SVOAs in Water GCMS

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### Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control

#### Batch AH64036 - SVOAs in Water GCMS

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<td>38.3</td>
<td>0.030</td>
<td>0.20</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>95.8</td>
<td>59-119</td>
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<tr>
<td>**Surrogate: 2-Fluorobiphenyl</td>
<td>31.2</td>
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<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>78.0</td>
<td>34-133</td>
<td>10-110</td>
<td>10-110</td>
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<td>**Surrogate: Nitrobenzene-d5</td>
<td>18.5</td>
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<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>46.2</td>
<td>36-131</td>
<td>20-120</td>
<td>10-120</td>
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<tr>
<td>**Surrogate: p-Terphenyl-d14</td>
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<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>90.4</td>
<td>35-156</td>
<td>10-156</td>
<td>10-156</td>
</tr>
</tbody>
</table>

| **Matrix Spike Dup (AH64036-MSD1)** | Source: 16H1178-04 | Prepared: 08/15/16 | Analyzed: 08/25/16 |         |      | | | | |
| Acenaphthene                   | 26.3   | 0.030| 0.20            | ug/L  | 40.0        | ND            | 65.7        | 49-106    | 6.66     25  |
| Acenaphthylene                 | 27.8   | 0.030| 0.20            | ug/L  | 40.0        | ND            | 69.4        | 69-108    | 0.753    25  |
| Anthracene                     | 36.6   | 0.030| 0.20            | ug/L  | 40.0        | ND            | 91.5        | 70-106    | 2.27     25  |
| Benzo (a) anthracene           | 33.2   | 0.040| 0.20            | ug/L  | 40.0        | ND            | 82.9        | 52-105    | 2.62     25  |
| Benzo (a) pyrene               | 30.4   | 0.040| 0.20            | ug/L  | 40.0        | ND            | 76.1        | 46-102    | 11.6     25  |
| Benzo (b) fluorethane          | 32.0   | 0.040| 0.20            | ug/L  | 40.0        | ND            | 80.0        | 42-112    | 20.5     25  |
| Benzo (g,h,i) perylene         | 27.7   | 0.040| 0.20            | ug/L  | 40.0        | ND            | 69.2        | 48-96     | 20.1     25  |
| Benzo (k) fluorethane          | 25.1   | 0.040| 0.20            | ug/L  | 40.0        | ND            | 62.8        | 44-102    | 30.7     25  |
| Chrysene                       | 38.2   | 0.040| 0.20            | ug/L  | 40.0        | ND            | 95.4        | 51-115    | 11.1     25  |
| Dibenz (a,h) anthracene        | 30.8   | 0.080| 0.20            | ug/L  | 40.0        | ND            | 77.1        | 50-115    | 13.6     25  |
| Fluoranthene                   | 38.7   | 0.030| 0.20            | ug/L  | 40.0        | ND            | 96.8        | 63-122    | 9.26     25  |
| Fluorene                       | 21.3   | 0.030| 0.20            | ug/L  | 40.0        | ND            | 53.2        | 51-105    | 11.2     25  |
| Indeno (1,2,3-cd) pyrene       | 29.6   | 0.050| 0.20            | ug/L  | 40.0        | ND            | 74.1        | 49-115    | 13.2     25  |

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>Reporting MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>%REC</th>
<th>Limits</th>
<th>RPD</th>
<th>Limit</th>
<th>Notes</th>
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<tr>
<td>Batch AH64036 - SVOAs in Water GCMS</td>
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<td>1.0</td>
<td>ug/L</td>
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<td>40.0</td>
<td>ND</td>
<td>27.7</td>
<td>25-107</td>
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<td>0.20</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>73.4</td>
<td>70-101</td>
<td>6.62</td>
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<tr>
<td>Pyrene</td>
<td>33.8</td>
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<td>0.20</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>84.6</td>
<td>59-119</td>
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<tr>
<td>Surrogate: 2-Fluorobiphenyl</td>
<td>26.4</td>
<td>ug/L</td>
<td>40.0</td>
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<td>66.1</td>
<td>34-133</td>
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<tr>
<td>Surrogate: Nitrobenzene-d5</td>
<td>18.4</td>
<td>ug/L</td>
<td>40.0</td>
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<td>46.0</td>
<td>36-131</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surrogate: p-Terphenyl-d14</td>
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<td>ug/L</td>
<td>40.0</td>
<td></td>
<td>87.4</td>
<td>35-156</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Notes and Definitions

> >8000

J Detected but below the Reporting Limit; therefore, result is an estimated concentration, detected but not quantified (DNQ).

OD-1 Odor described as "sulfur"

OD-2 Odor described as "septic"

OD-3 Odor described as "undetermined"

QM-05 The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

QM-08 The RPD was outside acceptance limits for MS/MSD, possibly due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

R-04 The Reporting Limits for this analysis are elevated due to sample foaming.

R-06 The Reporting Limits for this analysis have been raised to account for matrix interference.

T-2 Sample analyzed outside of recommended holding time per client.

U Analyte included in analysis, but not detected at or above MDL.

ND Analyte NOT DETECTED at or above the reporting limit

dry Sample results reported on a dry weight basis

REC Recovery

RPD Relative Percent Difference

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
# Chain of Custody - Work Order

Reports and Invoices delivered by email in PDF format

## Lab No: 1641178

<table>
<thead>
<tr>
<th>Company</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humboldt State University</td>
<td>Brad Finney</td>
</tr>
<tr>
<td>Environmental Resources &amp; Engineering</td>
<td>Address: 1 Harriet Street, Arcata CA 95521</td>
</tr>
<tr>
<td>Phone/Fax: 707-826-3918</td>
<td>Email Address: <a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
</tr>
</tbody>
</table>

### Sample Identification

<table>
<thead>
<tr>
<th>Sample</th>
<th>Date</th>
<th>Time</th>
<th>Matrix</th>
<th>Preservative</th>
<th>Container</th>
<th>Total Number of Containers per Sample ID</th>
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</thead>
<tbody>
<tr>
<td>C1</td>
<td>1/10/16</td>
<td>10 AM</td>
<td>Poly</td>
<td>HNO3 / H2SO4</td>
<td>40ml vial</td>
<td>1 x</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1 x</td>
<td>2 x</td>
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<td></td>
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<td>1 x</td>
<td>4 x</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>1 x</td>
<td>x</td>
</tr>
</tbody>
</table>

## Analysis Request

- 1L BRA (NP)
- 2 x 1L BRA (NP)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 4 x 40ml vials (HCl)
- 500mL BRA (NP)
- 1L poly (H2SO4)
- 500mL poly (NP)

## Field Sampler - Printed Name & Signature:

- Brad Finney

## CDPH Source Numbers:

- Cancel 625 SRF

## Other Information:

- CDPH Write On EDT Transmission? (Yes/No): No
- State System Number: If "Y" please enter the Source Number(s) in the column above
- CA Geotracker EDF Report? (Yes/No): No

**Revised by:**

**Received by:**

- UPS Ground via AAL acct # 894250
- 6/10/16 12

**Global ID:**

**Sampling Company Log Code:**

**Travel and Site Time:**

**Misc. Supplies:**

**Shipper:**

**PO Number:**

**Contractor:**

**Analysis:**

- Leachate
- Standard
  - 10 days
  - Rush: 5 days
  - 48 hours
  - Other: 2.8 days

**Temp upon Receipt:**

- Ukiah temp: 28°C
- Dublin temp: 10°C
- Other: 28°C

**Lab approval required:**

- Yes

**Analysis Information:**

- 625 DEHA - di-n-butyl-phthalate
- 625 SRF - SRF-Multicomp
- 200.7 - metals, see list below / 246.1 Hg
- 200.7 - Li and 200.7 - S (solid to liquid)
- 6260 DB VOCs
- Color and Odor
- Ammonia as N
- KNO3-N, Orthophosphate, Chloride, Turbidity
- KNO3-N, Orthophosphate, Chloride, Turbidity
- Handling & Disposal
- Flag Sample, MDL reporting
- Standard Excel EDF file

**Sample Notes:**

- 1L BRA (NP)
- 2 x 1L BRA (NP)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 4 x 40ml vials (HCl)
- 500mL BRA (NP)
- 1L poly (H2SO4)
- 500mL poly (NP)

**Per Client:**

- 625 SRF
**Chain of Custody - Work Order**

**Reports and Invoices delivered by email in PDF format**

Lab No: 16H1128  Pg 2 of 11

<table>
<thead>
<tr>
<th>Company</th>
<th>Humboldt State University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>Brad Finney</td>
</tr>
<tr>
<td>Address</td>
<td>Environmental Resources &amp; Engineering, 1 Harpsel Street, Arcata CA 95521</td>
</tr>
<tr>
<td>Phone/Fax</td>
<td>707-826-3918</td>
</tr>
<tr>
<td>Email</td>
<td><a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
</tr>
</tbody>
</table>

**Project Information**

- **Project ID:** Leachate
- **Project No:**
- **PO Number:**

**Analysis Request**

- **Container:**
  - 0.5L glass
- **Preservative:**
  - HNO3
- **Matrix:**
  - Soils
- **Total Number of Containers per Sample ID:**
  - 1 x 625 DBHA + 6-ml polyphosphate,
  - 850B VOCs
- **Chlorides and Turbidity:**
  - 200.7-7 and 200.7-S (sub to week)
- **Color and Odor:**
  - Handling & disposal, flag sample, lab report
- **Sample Notes or CDPH Source Numbers:**
  - 1L BRA (NP)
  - 4 x 40mL vials (HCl)
  - 500mL poly (HNO3)
  - 500mL poly (HNO3)
  - 250mL poly (NP)
  - 500mL BRA (NP)

**Sample Identification**

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sampling Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>C</td>
<td>08/10</td>
<td>1020</td>
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</tbody>
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**Relinquished by**

- **UPS Ground via AAL acct # 894250**

**Received by**

- **Date:** 6/10
- **Time:** 12

**CDPH Write On EDT Transmission?**

- **Yes**
- **No**

**State System Number:**

- **If "Y" please enter the Source Number(s) in the column above**

**CA Geotracker EDF Report?**

- **Yes**
- **No**

**Global ID:**

- **EDF ID (Email Address):**

**Travel and Site Time:**

- **Miles:**
- **Miles, Supplies:**
Chain of Custody - Work Order

Reports and Invoices delivered by email in PDF format

Lab No: 1611128 Pg 3 of 11

Company: Humboldt State University
Address: Environmental Resources & Engineering
1 Harpert Street, Arcata CA 95521

Invoice to (if different)

Company: Humboldt State University
Address: Environmental Resources & Engineering
1 Harpert Street, Arcata CA 95521

Contact: Brad Finney
Email address: brad.finney@humboldt.edu

Project Information

Project ID: Leachate
Project No:
PO Number:

Analysis Request

- 625 DEHA + di-butylphthalate
- 2007 Al Co Fe Mg Mn Na Sb
- 2007 Li and 2007 S (sub to Work)
- Chlorides and Turbidity
- Color and Color

Handling & disposal: Flag Sample, MDL reporting
Standard Enviromental File

TAT

- Standard 10 days
- Rush 5 days
- 48 hours
- Other

Temp upon Receipt °C

- Ukiah temp: 28
- Dublin temp:
- Elk Grove temp:

Sample Notes or CDPH Source Numbers:

- 1L BRA (NP)
- 4 x 40mL vials (HCl)
- 500mL poly (HNO3)
- 250mL poly (HNO3)
- 500mL BRA (NP)

Sample Identification

Sample ID: C3
Sampling Date: 10-10
Sampling Time: 10:54

40mL Vial
Poly
Class
SLeeve
Other
HCl
HNO3
H2SO4
Other
None
Water
Soil
Other

Total Number of Containers per Sample ID

- 1 x
- 4 x
- 1 x
- 1 x
- 1 x

Relinquished by

Reconciled by

Received by

UPS Ground via AAL acct # 894250

CDPH Write On EDT Transmission?

- Yes
- No

State System Number:

If "Y" please enter the Source Number(s) in the column above

CA Geotracker EDF Report?

- Yes
- No

Global ID:
EDF lo (Email Address):
Travel and Site Time:
Mileage:
Misc. Supplies:
## Chain of Custody - Work Order

**Reports and Invoices delivered by email in PDF format**

<table>
<thead>
<tr>
<th>Company:</th>
<th>Humboldt State University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt:</td>
<td>Brad Finney</td>
</tr>
<tr>
<td>Address:</td>
<td>Environmental Resources &amp; Engineering 1 Harpset Street, Arcata CA 95521</td>
</tr>
<tr>
<td>Email:</td>
<td><a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
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**Sample Identification**

<table>
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<tr>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
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<tr>
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<table>
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**Sample Notes or CDPH Source Numbers:**

- 1L BRA (NP)
- 2 x 1L BRA (NP)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 4 x 40ml vials (HCl)
- 500mL BRA (NP)
- 1L poly (H2SO4)
- 500mL poly (NP)

**Relinquished by**

- UPS Ground via AAL acct # 894250

**Received by**

- UPS Ground via AAL acct # 894250

**State System Number:**

- If "Y" please enter the Source Number(s) in the column above

**CA Geotracker EDF Report?**

- Yes

**Global ID:**

- Sampling Company Log Code:

**EDF to (Email Address):**

- Travel and Site Time:

**Signature below authorizes work under terms stated on reverse side.**
### Chain of Custody - Work Order

**Reports and Invoices delivered by email in PDF format**

**Lab No.** 16H1178  
**Pg. 5 of 11**

<table>
<thead>
<tr>
<th>Report to</th>
<th>Invoice to (if different)</th>
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<th>Analysis Request</th>
<th>TAT Temp upon Receipt °C</th>
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<td>Project ID:</td>
<td>Leachate</td>
<td>Standard 10 days</td>
</tr>
<tr>
<td>Brad Finney</td>
<td>Email address:</td>
<td>Project No:</td>
<td></td>
<td>Rush: 5 days</td>
</tr>
<tr>
<td>Environmental Resources &amp; Engineering</td>
<td>Address:</td>
<td>PO Number:</td>
<td></td>
<td>Other: 48 hours</td>
</tr>
<tr>
<td>1 Harpest Street, Arcata CA 95521</td>
<td>Phone/Fax: 707-826-3918</td>
<td></td>
<td></td>
<td>Other: Other days</td>
</tr>
<tr>
<td>Email Address: <a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
<td></td>
<td></td>
<td></td>
<td>Lab approval required</td>
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</table>

**Field Sampler - Printed Name & Signature:**

**Sample Identification**

<table>
<thead>
<tr>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
<th>Total Number of Containers per Sample ID</th>
<th>625 DEHA + Octyl-phenylsilicate</th>
<th>625B VOCs</th>
<th>2007-1 Al, Ba, Ca, Fe, Mg, Mn, Na, Sb</th>
<th>2007-1 Li, and 2007-2 S (sub to week)</th>
<th>Chloride and Turbidity</th>
<th>Color and Odor</th>
<th>Handling &amp; disposal</th>
<th>OBS Sample, IGL, reporting</th>
<th>Standard Excel EDF file</th>
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<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Sample Notes or CDPH Source Numbers:**

- 1L BRA (NP)
- 4 x 40mL vials (HCl)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 250mL poly (NP)
- 500mL BRA (NP)

**Relinquished by**

- UPS Ground via AAL acct # 894250

**Received by**

- UPS Ground via AAL acct # 894250

**Date** 12/3/10  
**Time** 10:45a

**CDPH Write On EDT Transmission?**

- Yes  
- No

**State System Number:**

**If Y please enter the Source Number(s) in the column above**

**CA Geotracker EDF Report?**

- Yes  
- No

**Global ID:**

**Sampling Company Log Code:**

**EDF to (Email Address):**

**Travel and Site Time:**

**Mileage:**

**Mac. Supplies:**
# Chain of Custody - Work Order

**Reports and Invoices delivered by email in PDF format**

**Lab No:** 16H1708  **Pg:** 6 of 17

### Company:
- **Humboldt State University**
  - **Address:** Environmental Resources & Engineering  
    1 Harpstreet, Arcata CA 95521
  - **Contact:** Brad Finney  
    - **Email Address:** brad.finney@humboldt.edu

### Project Information
- **Project ID:** Leachate
- **Project No:**
- **PO Number:**

### Analysis Request

<table>
<thead>
<tr>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
<th>Total Number of Containers per Sample ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>40mL Vial</td>
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<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Glass</td>
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<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sleeve</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Other</td>
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<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HCl</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HNO3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H2SO4</td>
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<td>X</td>
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<tr>
<td>Other</td>
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<td>X</td>
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<tr>
<td>None</td>
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<tr>
<td>Soil</td>
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<td>X</td>
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</tr>
<tr>
<td>Other</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

### TAT
- **Standard:** 10 days
- **RUSH:** 5 days
- **Other:** 48 hours

### Temp upon Receipt
- **Ukiah temp:**
- **Dublin temp:**
- **Elk Grove temp:**

### Sample Notes or CDPH Source Numbers:
- 1L BRA (NP)
- 4 x 40mL vials (HCl)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 250mL poly (NP)
- 500mL BRA (NP)

### Sample Identification

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sampling Date</th>
<th>Time</th>
</tr>
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<tbody>
<tr>
<td>C6</td>
<td>8/10/12</td>
<td>12PM</td>
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</tbody>
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### Relinquished by
- UPS Ground via AAL acct # 894250

### Received by
- UPS Ground via AAL acct # 894250

### CDPH Write On EDT Transmission?
- Yes

### State System Number:

If "Y" please enter the Source Number(s) in the column above

### CA Geotracker EDF Report?
- No

**Global ID:**
- **EDF (Email Address):**

**Travel and Site Time:**
- **In hours:**
- **In minutes:**
**Sample Identification**

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sampling Date</th>
<th>Time</th>
<th>Poly</th>
<th>Glass</th>
<th>Sheeve</th>
<th>Other</th>
<th>HCl</th>
<th>HNO3</th>
<th>HS204</th>
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</tbody>
</table>

**Analysis Request**

- 625 DEHA + 8-Nitro-Phthalate
- 82608 VOCs
- S5
- 2007-7 All Ba Co Fe Mn Na Sb
- 2007-7 Li and 2007-5 (sub in week)

**Results**

- Chlorides and Turbidity: xx
- Color and Odor: xx
- Handling & Disposal: xx
- Sample Report: xx

**Sample Notes or CDPH Source Numbers**

- 1L BRA (NP)
- 4 x 40mL vials (HCl)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 250mL poly (NP)
- 500mL BRA (NP)

**Chain of Custody - Work Order**

- Lab No: V6H1178
- Pg 7 of 11

- **Company:** Humboldt State University
- **Contact:** Brad Finney
- **Address:** Environmental Resources & Engineering

- **Analysis Request TAT:**
  - Standard 10 days
  - Rush 5 days
  - 48 hours
  - Other: days

- **Temp upon Receipt °C:**
  - Ukiah temp: 2.8
  - Dublin temp: 
  - Elk Grove temp: 

- **Sample Notes or CDPH Source Numbers:**
  - 1L BRA (NP)
  - 4 x 40mL vials (HCl)
  - 500mL poly (HNO3)
  - 500mL poly (HNO3)
  - 250mL poly (NP)
  - 500mL BRA (NP)

- **Relinquished by:**
  - UPS Ground via AAL acct # 894250

- **Received by:**
  - UPS Ground via AAL acct # 894250

- **CDPH Write On EDT Transmission?**
  - Yes

- **State System Number:**
  - If "Y" please enter the Source Number(s) in the column above

- **CA Geotracker EDF Report?**
  - Yes
### Chain of Custody - Work Order

**Reports and Invoices delivered by email in PDF format**

**Lab No:** 16041178  **Pg. 8 of 11**

#### Project Information

- **Company:** Humboldt State University
- **Company Contact:** Brad Finney
- **Address:** Environmental Resources & Engineering, 1 Harst Street, Arcata CA 95521
- **Phone/Fax:** 707-926-3918
- **Email Address:** brad.finney@humboldt.edu

#### Project Information

- **Project ID:** Leachate
- **Project No:**
- **PO Number:**

#### Analysis Request

- **TAT:** Standard 10 days
- **Temp upon Receipt °C:**
  - Ukiah temp: 2.8
  - Dublin temp: 0
  - Elk Grove temp: 0

#### Sample Identification

<table>
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<th>Sample Identification</th>
<th>Sampling Date</th>
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<th>40mL Vial</th>
<th>Poly</th>
<th>Glass</th>
<th>Silv...</th>
<th>Other</th>
<th>HNO3</th>
<th>H2SO4</th>
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<td>C8</td>
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#### Sample Notes or CDPH Source Numbers:

- 1L BRA (NP)
- 4 x 40mL vials (HCl)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 250mL poly (NP)
- 500mL BRA (NP)

#### Relinquished by

- **UPS Ground via AAL acct # 894250**

#### Received by

- **UPS Ground via AAL acct # 894250**

#### CDPH Write On EDT Transmission?

- Yes
- No

#### CA Geotracker EDF Report?

- Yes
- No
**Chain of Custody - Work Order**

Reports and Invoices delivered by email in PDF format

Lab No: 16H1128  Pg 9 of 11

**Company:** Humboldt State University  
**Contact:** Brad Finney  
**Address:** Environmental Resources & Engineering  
1 Harp Street, Arcata CA 95521  
**Phone/Fax:** 707-825-3918  
**Email Address:** brad.finney@humboldt.edu

Field Sampler - Printed Name & Signature:

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sampling Date/Time</th>
<th>40cm Vin</th>
<th>Poly</th>
<th>Glass</th>
<th>Sleeve</th>
<th>Other</th>
<th>HCl</th>
<th>HNO3</th>
<th>H2SO4</th>
<th>Other</th>
<th>Name</th>
<th>Water</th>
<th>Soil</th>
<th>Other</th>
<th>Total Number of Containers per Sample ID</th>
<th>625 DEHA + di-n-butylphthalate</th>
<th>8269R VOCs</th>
<th>2007-1 Al Ba Co Fe Mg Mn Na Sb</th>
<th>Chloride and Turbidity</th>
<th>Color and Odor</th>
<th>Handling &amp; Disposal</th>
<th>Hazard Sample, MDR</th>
<th>Standard Excel EDF file</th>
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<tr>
<td>CA</td>
<td>6/10/18 10 AM</td>
<td>x</td>
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<td>x</td>
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</table>

**Relinquished by:**  
**Received by:** UPS Ground via AAL acct # 894250

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>6/10/18</td>
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<table>
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<tr>
<th>CDPH Write On EDT Transmission?</th>
<th>Yes</th>
<th>No</th>
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<tr>
<td>State System Number:</td>
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<tr>
<td><strong>CA Geotracker EDF Report?</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
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Global ID:  
Sampling Company Log Code:  
EDF to (Email Address):  
Travel and Site Time:  
Mileage:  
Misc. Supplies:
# Chain of Custody - Work Order

Reports and Invoices delivered by email in PDF format

---

**Company:** Humboldt State University  
**Address:** 1 Harpst Street, Arcata CA 95521  
**Contact:** Brad Finney  
**Phone/Fax:** 707-826-3918  
**Email Address:** hved.finney@humboldt.edu

**Sample Identification**

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Time</th>
<th>40ml Vial</th>
<th>Poly</th>
<th>Glass</th>
<th>Sleeve</th>
<th>Other</th>
<th>HCl</th>
<th>HNO3</th>
<th>HSO4</th>
<th>Other</th>
<th>Name</th>
<th>Water</th>
<th>Soil</th>
<th>Other</th>
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<tbody>
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**Relinquished by:**  
**Received by:** UPS Ground via AAL acct # 894250

---

**Analysis Request**

**525 DEHA + 6-n-hydroxyhexahydro-DEHA**

---

**Sample Notes or CDPH Source Numbers:**

- 1L BRA (NP)
- 4 x 40ml vials (HCl)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 250mL poly (NP)
- 500mL BRA (NP)

---

**CDDP Write On EDT Transmission?**  
○ Yes  ○ No

**State System Number:**

If "Y" please enter the Source Number(s) in the column above

**CA Geotracker EDF Report?**

○ Yes  ○ No

**Global ID:**

EDF to (Email Address):  
Travel and Date Time:  
Meager:  
Misc. Supplies:
### Chain of Custody - Work Order

**Reports and invoices delivered by email in PDF format**

**Lab No:** 1641178  
**Pg:** 11 of 17

<table>
<thead>
<tr>
<th>Company</th>
<th>Humboldt State University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>Environmental Resources &amp; Engineering 1 Harst Street, Arcata CA 95521</td>
</tr>
<tr>
<td>Phone/Fax</td>
<td>707-826-3918</td>
</tr>
<tr>
<td>Email Address</td>
<td><a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Report to</th>
<th>Humboldt State University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>Environmental Resources &amp; Engineering 1 Harst Street, Arcata CA 95521</td>
</tr>
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<td>Phone/Fax</td>
<td>707-826-3918</td>
</tr>
<tr>
<td>Email Address</td>
<td><a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
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</table>

<table>
<thead>
<tr>
<th>Invoice to (If different)</th>
<th>Leachate</th>
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<tbody>
<tr>
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<td>Leachate</td>
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<tr>
<td>Project No</td>
<td></td>
</tr>
<tr>
<td>PO Number</td>
<td></td>
</tr>
</tbody>
</table>

**Analysis Request**

- **Standard 10 days**
- **RUSH: 5 days**
- **48 hours**
- **Other:**

**TAT**

- **Temp upon Receipt °C**
  - Ukiah temp: 2.8
  - Dublin temp:  
  - Elk Grove temp:  

**Sample Identification**

<table>
<thead>
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<th>Sampling Date</th>
<th>Sampling Time</th>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
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<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Total Number of Containers per Sample ID:**

- 1 x
- 4 x
- 1 x

**Handling & disposal:**

- Flag Sample, EDF reporting
- Standard EDF file

**Sample Notes or CDPH Source Numbers:**

- 1L BRA (NP)
- 4 x 40mL vials (HCl)
- 500mL poly (HNO3)
- 500mL poly (HNO3)
- 250mL poly (NP)
- 500mL BRA (NP)

**CDPH Write On EDT Transmission?**

- Yes
- No

**State System Number:**

- If "Y" please enter the Source Number(s) in the column above

**CA Geotracker EDF Report?**

- Yes
- No

**Global ID:**

- Sampling Company Log Code:

**Travel and Site Time:**

- Mileage:
- Misc. Supplies:
Carpet - 2 month soak results
Enclosed are the results of analyses for samples received by the laboratory on 09/15/16 10:00. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeanette L. Poplin For David S. Pingatore
Project Manager
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Laboratory ID</th>
<th>Matrix</th>
<th>Date Sampled</th>
<th>Date Received</th>
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<tbody>
<tr>
<td>C1</td>
<td>16I1417-01</td>
<td>Water</td>
<td>09/13/16 20:00</td>
<td>09/15/16 10:00</td>
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</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### C1

1611417-01(Water)

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<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Metals by EPA 200 Series Methods</strong></td>
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<tr>
<td>Aluminum</td>
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<td>0.020</td>
<td>mg/L</td>
<td>0.050</td>
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<td>9/27/16 12:20</td>
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<td>EPA 200.7</td>
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<td>EPA 200.7</td>
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<td>9/27/16 12:20</td>
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<td>Cadmium</td>
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<td>9/27/16 12:20</td>
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<td>U</td>
</tr>
<tr>
<td>Magnesium</td>
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<td>mg/L</td>
<td>1.0</td>
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</tr>
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### Volatile Organic Compounds by EPA Method 8260B

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**Surrogate: Dibromofluoromethane**

- **Surrogate: Toluene-d8**
- **Surrogate: Bromofluorobenzene**

### Additional Semivolatile Organic Compounds by EPA Method 625

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**Surrogate: 2-Fluorobiphenyl**

- **Surrogate: Nitrobenzene-d5**
- **Surrogate: p-Terphenyl-d14**

### Semivolatile Organic Compounds by EPA Method 625 SIM

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**Reported:** Humboldt State Univ - Env. Resources & Engineering  
1 Harpst Street  
Arcata, CA, 95521  

**Reporting**  
C1  
16I1417-01(Water)  

**Semivolatile Organic Compounds by EPA Method 625 SIM**

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# Metals by EPA 200 Series Methods - Quality Control

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1 Harpst Street
Arcata, CA, 95521

Project Manager: Brad Finney
Project: Special Leachate Project
Project Number: -
Reported: 09/29/16 16:06

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## Metals by EPA 200 Series Methods - Quality Control

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Metals by EPA 200 Series Methods - Quality Control

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**Batch AI63737 - Metals Digest**

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### Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

#### Batch AI63543 - VOAs in Water GCMS

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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AI63543 - VOAs in Water GCMS**

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<th>Analyte</th>
<th>Result</th>
<th>Reporting MDL</th>
<th>Reporting Limit</th>
<th>Spike Level (ug/L)</th>
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<th>%REC Limits</th>
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**Surrogate: Dibromofluoromethane**

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AI63543 - VOAs in Water GCMS**

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### Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA, 95521

Project: Special Leachate Project
Project Number: -

Reported: 09/29/16 16:06

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## Volatile Organic Compounds by EPA Method 8260B - Quality Control

### Batch AI63543 - VOAs in Water GCMS

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<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
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<th>RPD</th>
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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

**Batch AI63543 - VOAs in Water GCMS**

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<th>Result</th>
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<th>Reporting Limit</th>
<th>Units</th>
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<th>Source Result</th>
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<th>RPD</th>
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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

#### Batch AI63543 - VOAs in Water GCMS

<table>
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<tr>
<th>Analyte</th>
<th>Result</th>
<th>Reporting MDL</th>
<th>Limit Units</th>
<th>Spike</th>
<th>Source Level</th>
<th>%REC</th>
<th>%REC Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
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### Batch AI63543 - VOAs in Water GCMS

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<th>Analyte</th>
<th>Result</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
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QM-05

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Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA 95521

Project Manager: Brad Finney
Project: Special Leachate Project
Reported: 09/29/16 16:06

Volatile Organic Compounds by EPA Method 8260B - Quality Control

Batch AI63543 - VOAs in Water GCMS

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<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD</th>
<th>Limit</th>
<th>Notes</th>
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Matrix Spike Dup (AI63543-MSD1)

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## Volatile Organic Compounds by EPA Method 8260B - Quality Control

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<th>Analyte</th>
<th>Result (ug/L)</th>
<th>%REC</th>
<th>RPD Limit</th>
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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

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### Additional Semivolatile Organic Compounds by EPA Method 625 - Quality Control

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### Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control

#### Batch AI63654 - SVOAs in Water GCMS

**Blank (AI63654-BLK1)**  
Prepared: 09/19/16  Analyzed: 09/23/16

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**LCS (AI63654-BS1)**  
Prepared: 09/19/16  Analyzed: 09/23/16

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### Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control

#### Batch AI63654 - SVOAs in Water GCMS

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#### LCS Dup (AI63654-BSD1)

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<td>40.0</td>
<td>ND</td>
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<td>ug/L</td>
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<td>61.5</td>
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<td>Pyrene</td>
<td>35.3</td>
<td>0.20</td>
<td>0.20</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>88.4</td>
<td>59-119</td>
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<td></td>
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**Surrogate:** 2-Fluorobiphenyl | 19.1 | ug/L | 40.0 | 47.7 | 34-133 | |
**Surrogate:** Nitrobenzene-d5 | 15.4 | ug/L | 40.0 | 38.4 | 36-131 | |
**Surrogate:** p-Terphenyl-d14 | 33.4 | ug/L | 40.0 | 83.6 | 35-156 | |

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>%REC</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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<td>Dibenz (a,h) anthracene</td>
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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Semivolatile Organic Compounds by EPA Method 625 SIM - Quality Control

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL Limit</th>
<th>Reporting Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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<td>102</td>
<td>52-106</td>
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<tr>
<td>Naphthalene</td>
<td>16.6</td>
<td>0.090</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>41.6</td>
<td>47-107</td>
<td>28.1, 25</td>
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<tr>
<td>Phenanthrene</td>
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<td>0.10</td>
<td>ug/L</td>
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<td>ND</td>
<td>67.2</td>
<td>45-101</td>
<td>8.90, 25</td>
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<tr>
<td>Pyrene</td>
<td>35.9</td>
<td>0.20</td>
<td>ug/L</td>
<td>40.0</td>
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<td>89.8</td>
<td>59-119</td>
<td>1.57, 25</td>
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<tr>
<td>Surrogate: 2-Fluorobiphenyl</td>
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<td>35-156</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

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Notes and Definitions

> >8000

J Detected but below the Reporting Limit; therefore, result is an estimated concentration, detected but not quantified (DNQ).

OD-1 Odor described as "UNDETERMINED"

QM-05 The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

QM-08 The RPD was outside acceptance limits for MS/MSD, possibly due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

QM-4X The spike recovery was outside of QC acceptance limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

R-04 The Reporting Limits for this analysis are elevated due to sample foaming.

R-06 The Reporting Limits for this analysis have been raised to account for matrix interference.

T-1 This sample was received outside recommended holding time.

U Analyte included in analysis, but not detected at or above MDL.

ND Analyte NOT DETECTED at or above the reporting limit

dry Sample results reported on a dry weight basis

REC Recovery

RPD Relative Percent Difference
### Chain of Custody - Work Order

Reports and Invoices delivered by email in PDF format

| Lab No | 1671417 | Pg | of |

#### Report to
- Humboldt State University
- Brad Finney
- Environmental Resources & Engineering
- 1 Harpt Street, Arcata CA 95521
- 707-826-3918
- brad.finney@humboldt.edu

#### Invoice to (if different)

#### Project Information
- **Project ID:** Leachate
- **Project No:**
- **PO Number:**

#### Signature below authorizes work under terms stated on reverse side.

#### Analysis Request

<table>
<thead>
<tr>
<th>Total Number of Containers per Sample ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>625 mls, SSF SIM Mode</td>
</tr>
<tr>
<td>2007 metals, see list below / 2951.1 kg</td>
</tr>
</tbody>
</table>

#### TAT
- Standard 10 days
- RUSH: 5 days
- Other: 48 hours

#### Temp upon Receipt °C
- Ukiah temp:
- Dublin temp:
- Elk Grove temp:

#### Field Sampler - Printed Name & Signature:
**BRAD FINNEY**

#### Sample Identification

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Sampling Time</th>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
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<tbody>
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<td>3 PM</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
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<td></td>
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<td>x</td>
<td>x</td>
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</tbody>
</table>

#### Sample Notes or CDPH Source Numbers:
- 1L BRA (NP)
- 2 x 1L BRA (NP)
- 250mL poly (HNO3)
- 250mL poly (HNO3)
- 4 x 40mL vials (HCl)
- 500mL BRA (NP)
- 1L poly (H2SO4)
- 500mL poly (NP)

#### CDPH Write On EDT Transmission?
- Yes
- No

#### State System Number:
- If "Y" please enter the Source Number(s) in the column above

#### CA Geotracker EDF Report?
- Yes
- No

#### Relinquished by
- **B. FINNEY**

#### Received by
- UPS Ground via AAL acct # 894250

#### Date
- 9/15/16

#### Time
- 1000
Carpet Backing Powder - Dry Samples
ELAP Certificates 1551, 2728, and 2922

13 December 2016

Humboldt State Univ - Env. Resources & Engineering
Attn: Brad Finney
1 Harpst Street
Arcata, CA 95521
RE: Haz - CAM TTLC Profile
Work Order: 16K2270

Enclosed are the results of analyses for samples received by the laboratory on 11/28/16 09:00. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeanette L. Poplin For David S. Pingatore
Project Manager
<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Laboratory ID</th>
<th>Matrix</th>
<th>Date Sampled</th>
<th>Date Received</th>
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<tbody>
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<td>Soil</td>
<td>11/23/16 09:00</td>
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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
## Metals by EPA 6000/7000 Series Methods

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<th>Analyte</th>
<th>Result</th>
<th>MDL Limit</th>
<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Analyst</th>
<th>Notes</th>
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<td>11/30/16 13:58</td>
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<td>11/30/16 13:58</td>
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### Conventional Chemistry Parameters by APHA/EPA Methods

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<th>Dilution</th>
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<th>Analyzed</th>
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<th>Analyst</th>
<th>Notes</th>
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### Anions by EPA Method 300.0

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<th>Analyst</th>
<th>Notes</th>
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Page 4 of 29
### Volatile Organic Compounds by EPA Method 8260B

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## Humboldt State Univ - Env. Resources & Engineering

1 Harpst Street

Arcata, CA 95521

### Project Manager: Brad Finney

### Project: Haz - CAM TTLC Profile

### Project Number: [none]

### Reported: 12/13/16 16:50

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## Volatile Organic Compounds by EPA Method 8260B

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<th>Analyzed</th>
<th>Method</th>
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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Organochlorine Pesticides and PCBs by EPA Method 8081/8082

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### Semivolatile Organic Compounds by EPA Method 8270C

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<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL Limit</th>
<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<th>Analyte</th>
<th>Result</th>
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<th>Units</th>
<th>Dilution</th>
<th>Batch Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Analyst</th>
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**Surrogate:** 2-Fluorobiphenyl 97.5 % 61-117 2-Fluorophenol 83.5 % 50-113

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Semivolatile Organic Compounds by EPA Method 8270C

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| Surrogate: Nitrobenzene-d5 | 95.0 % | 47-123 | AL63004 | 12/01/16 06:54 | 12/08/16 17:12 | EPA 8270C | NBH |
| Surrogate: p-Terphenyl-d14 | 118 %  | 65-133 | AL63004 | 12/01/16 06:54 | 12/08/16 17:12 | EPA 8270C | NBH |
| Surrogate: Phenol-d6       | 91.5 % | 49-119 | AL63004 | 12/01/16 06:54 | 12/08/16 17:12 | EPA 8270C | NBH |
| Surrogate: 2,4,6-Tribromophenol | 90.0 % | 52-129 | AL63004 | 12/01/16 06:54 | 12/08/16 17:12 | EPA 8270C | NBH |

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### Metals by EPA 6000/7000 Series Methods - Quality Control

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### Metals by EPA 6000/7000 Series Methods - Quality Control

#### Batch AK63995 - EPA 3051 Microwave

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### Metals by EPA 6000/7000 Series Methods - Quality Control

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## Metals by EPA 6000/7000 Series Methods - Quality Control

### Batch AK63995 - EPA 3051 Microwave

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*The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.*
### Humboldt State Univ - Env. Resources & Engineering

1 Harpset Street
Arcata, CA, 95521

**Project Manager:** Brad Finney
**Project:** Haz - CAM TTLC Profile
**Project Number:** [none]

Reported: 12/13/16 16:50

---

**Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control**

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<th>Reporting</th>
<th>Spike</th>
<th>Source</th>
<th>%REC</th>
<th>RPD</th>
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<td>mg/kg</td>
<td>56600</td>
<td>98.0</td>
<td>80-120</td>
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</table>

| **Batch AL63328 - General Preparation** |
| LCS (AL63328-BS1)               |        | Prepared & Analyzed: 12/09/16 |        |      |     |     |       |
| Ammonia as NH3                  | 5.75   | 0.20      | 0.50  | mg/kg  | 6.10 | 94.2| 90-110|       |
| **LCS Dup (AL63328-BSD1)**     |        | Prepared & Analyzed: 12/09/16 |        |      |     |     |       |
| Ammonia as NH3                  | 5.85   | 0.20      | 0.50  | mg/kg  | 6.10 | 96.0| 90-110| 1.83  | 10    |

---

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Anions by EPA Method 300.0 - Quality Control

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### Humboldt State Univ - Env. Resources & Engineering

**1 Harpst Street, Arcata, CA 95521**

**Project Manager:** Brad Finney

**Reported:** 12/13/16 16:50

### Project: Haz - CAM TTLC Profile

**Project Number:** [none]

### Volatile Organic Compounds by EPA Method 8260B - Quality Control

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<th>RPD</th>
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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

#### Batch AK63979 - VOAs in Soil GCMS

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<td>mg/kg</td>
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| LCS Dup (AK63979-BSD1)        | Prepared: 11/29/16 Analyzed: 11/30/16 |
| Benzene                       | 4.45   | 0.070           | 0.17        | mg/kg         | 4.32        | 103       | 58-143 1.92 25 |
| Chlorobenzene                 | 4.47   | 0.070           | 0.17        | mg/kg         | 4.32        | 104       | 76-145 0.778 25 |
| 1,1-Dichloroethene            | 4.52   | 0.080           | 0.17        | mg/kg         | 4.32        | 105       | 77-142 3.79 25 |
| Toluene                       | 4.50   | 0.070           | 0.17        | mg/kg         | 4.32        | 104       | 55-158 0.347 25 |
| Trichloroethene               | 4.33   | 0.080           | 0.17        | mg/kg         | 4.32        | 100       | 71-139 1.25 25 |
| Surrogate: Bromofluorobenzene | 5.05   |                 |             | mg/kg         | 4.32        | 117       | 38-163         |
| Surrogate: Dibromofluoromethane| 4.98  |                 |             | mg/kg         | 4.32        | 115       | 39-154         |
| Surrogate: Toluene-d8         | 5.24   |                 |             | mg/kg         | 4.32        | 121       | 51-161         |

| Matrix Spike (AK63979-MS1)    | Source: 16K2397-01 Prepared: 11/29/16 Analyzed: 11/30/16 |
| Benzene                       | 4.24   | 0.070           | 0.17        | mg/kg         | 4.29        | ND        | 98.9 37-149    |
| Chlorobenzene                 | 4.31   | 0.070           | 0.17        | mg/kg         | 4.29        | ND        | 101 44-157     |
| 1,1-Dichloroethene            | 4.29   | 0.080           | 0.17        | mg/kg         | 4.29        | ND        | 100 38-165     |
| Toluene                       | 4.41   | 0.070           | 0.17        | mg/kg         | 4.29        | ND        | 103 22-166     |
| Trichloroethene               | 4.14   | 0.080           | 0.17        | mg/kg         | 4.29        | ND        | 96.5 51-146    |
| Surrogate: Bromofluorobenzene | 4.67   |                 |             | mg/kg         | 4.29        | 109       | 38-163         |
| Surrogate: Dibromofluoromethane| 4.55  |                 |             | mg/kg         | 4.29        | 106       | 39-154         |
| Surrogate: Toluene-d8         | 4.80   |                 |             | mg/kg         | 4.29        | 112       | 51-161         |

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### Humboldt State Univ - Env. Resources & Engineering

Project: Haz - CAM TTLC Profile

Project Manager: Brad Finney

Reported: 12/13/16 16:50

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### Volatile Organic Compounds by EPA Method 8260B - Quality Control

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### Organochlorine Pesticides and PCBs by EPA Method 8081/8082 - Quality Control

Batch AK63950 - EPA 3540C Soxhlet

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**Surrogate: Dibutylchlorendate**

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<th>Spike Level</th>
<th>Source</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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<td>50-120</td>
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Humboldt State Univ - Env. Resources & Engineering  
1 Harpst Street, Arcata, CA, 95521

Project: Haz - CAM TTLC Profile  
Project Manager: Brad Finney  
Reported: 12/13/16 16:50

Organochlorine Pesticides and PCBs by EPA Method 8081/8082 - Quality Control

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<th>Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
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LCS Dup (AK63950-BS1)  
Prepared: 11/29/16  Analyzed: 12/02/16

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<td>33-148</td>
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</table>

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Organochlorine Pesticides and PCBs by EPA Method 8081/8082 - Quality Control

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<tr>
<th>Batch AK63950 - EPA 3540C Soxhlet</th>
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<td>Prepared: 11/29/16 Analyzed: 12/02/16</td>
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- Heptachlor epoxide: Result 0.0126, Reporting Limit 0.0010, Spike Limit 0.0050, Units mg/kg, Source 0.0120, %REC 105, Limit 37-142, RPD 10.7, Notes 30
- Methoxychlor: Result 0.0129, Reporting Limit 0.0020, Spike Limit 0.0050, Units mg/kg, Source 0.0120, %REC 107, Limit 36-148, RPD 17.7, Notes 30
- Surrogate: Dibutylchloroendate: Result 0.0310, Reporting Limit 0.0408, Units mg/kg, Source 75.9, Limit 50-120

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<td>Prepared: 11/29/16 Analyzed: 12/03/16</td>
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- Aldrin: Result 0.0117, Reporting Limit 0.0035, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 97.6, RPD 51-122, Notes J
- alpha-BHC: Result 0.0103, Reporting Limit 0.0035, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 85.9, RPD 54-116, Notes J
- beta-BHC: Result 0.00759, Reporting Limit 0.0035, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 63.3, RPD 27-193, Notes J
- delta-BHC: Result 0.0114, Reporting Limit 0.0030, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 95.2, RPD 64-141, Notes J
- gamma-BHC (Lindane): Result 0.00105, Reporting Limit 0.0035, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 87.4, RPD 55-121, Notes J
- 4,4´-DDE: Result 0.00943, Reporting Limit 0.0045, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 78.6, RPD 57-128, Notes J
- 4,4´-DDD: Result 0.0104, Reporting Limit 0.010, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 86.9, RPD 46-144, Notes J
- 4,4´-DDT: Result 0.0115, Reporting Limit 0.0050, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 95.7, RPD 44-154, Notes J
- Dieldrin: Result 0.00854, Reporting Limit 0.0045, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 71.2, RPD 58-124, Notes J
- Endosulfan I: Result ND, Reporting Limit 0.010, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 58-125, Notes QM-05, U
- Endosulfan II: Result 0.00845, Reporting Limit 0.0040, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 70.4, RPD 51-139, Notes J
- Endosulfan sulfate: Result 0.00752, Reporting Limit 0.0050, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 62.7, RPD 51-138, Notes J
- Endrin: Result ND, Reporting Limit 0.010, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 55-158, Notes QM-05, U
- Endrin aldehyde: Result 0.00677, Reporting Limit 0.0035, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 56.4, RPD 34-146, Notes J
- Heptachlor: Result 0.0112, Reporting Limit 0.010, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 93.1, RPD 42-150, Notes J
- Heptachlor epoxide: Result 0.00979, Reporting Limit 0.0050, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 81.5, RPD 53-120, Notes J
- Methoxychlor: Result ND, Reporting Limit 0.010, Spike Limit 0.025, Units mg/kg, Source 0.0120, %REC ND, Limit 41-157, Notes QM-05, U
- Surrogate: Dibutylchloroendate: Result 0.0281, Reporting Limit 0.0408, Units mg/kg, Source 69.0, Limit 50-120

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### Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

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<tr>
<th>Analyte</th>
<th>Result</th>
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**Semivolatile Organic Compounds by EPA Method 8270C - Quality Control**

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<td>mg/kg</td>
<td>4.00</td>
<td>93.6</td>
<td>47-123</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surrogate: p-Terphenyl-d14</td>
<td>4.63</td>
<td>mg/kg</td>
<td>4.00</td>
<td>116</td>
<td>63-133</td>
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<tr>
<td>Surrogate: Phenol-d6</td>
<td>3.68</td>
<td>mg/kg</td>
<td>4.00</td>
<td>92.0</td>
<td>49-119</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surrogate: 2,4,6-Tribromophenol</td>
<td>4.40</td>
<td>mg/kg</td>
<td>4.00</td>
<td>110</td>
<td>52-129</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LCS (AL63004-BS1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>1.80</td>
<td>0.020</td>
<td>0.062</td>
<td>mg/kg</td>
<td>2.00</td>
<td>89.8</td>
<td>35-99</td>
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<tr>
<td>4-Chloro-3-methylphenol</td>
<td>2.98</td>
<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>4.00</td>
<td>74.4</td>
<td>55-105</td>
</tr>
<tr>
<td>2-Chlorophenol</td>
<td>3.30</td>
<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>4.00</td>
<td>82.5</td>
<td>55-100</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>1.77</td>
<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>2.00</td>
<td>88.4</td>
<td>55-100</td>
</tr>
<tr>
<td>2,4-Dinitrotoluene</td>
<td>1.84</td>
<td>0.18</td>
<td>0.33</td>
<td>mg/kg</td>
<td>2.00</td>
<td>91.8</td>
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<tr>
<td>N-Nitrosodi-n-propylamine</td>
<td>1.71</td>
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<td>0.33</td>
<td>mg/kg</td>
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<td>4-Nitrophenol</td>
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<td>1.6</td>
<td>mg/kg</td>
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<td>mg/kg</td>
<td>4.00</td>
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<tr>
<td>Phenol</td>
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<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>4.00</td>
<td>79.7</td>
<td>54-95</td>
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<tr>
<td>Pyrene</td>
<td>2.45</td>
<td>0.030</td>
<td>0.062</td>
<td>mg/kg</td>
<td>2.00</td>
<td>123</td>
<td>50-135</td>
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<td>1,2,4-Trichlorobenzene</td>
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<tr>
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<td>4.00</td>
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<tr>
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<td>3.53</td>
<td>mg/kg</td>
<td>4.00</td>
<td>88.3</td>
<td>50-113</td>
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<tr>
<td>Surrogate: Nitrobenzene-d5</td>
<td>3.83</td>
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<td>4.00</td>
<td>95.7</td>
<td>47-123</td>
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<tr>
<td>Surrogate: p-Terphenyl-d14</td>
<td>4.84</td>
<td>mg/kg</td>
<td>4.00</td>
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<td>63-133</td>
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<tr>
<td>Surrogate: Phenol-d6</td>
<td>3.36</td>
<td>mg/kg</td>
<td>4.00</td>
<td>84.0</td>
<td>49-119</td>
<td></td>
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<tr>
<td>Surrogate: 2,4,6-Tribromophenol</td>
<td>3.98</td>
<td>mg/kg</td>
<td>4.00</td>
<td>99.6</td>
<td>52-129</td>
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<td></td>
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<tr>
<td><strong>LCS Dup (AL63004-BSD1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>1.88</td>
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<tr>
<td>4-Chloro-3-methylphenol</td>
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<td>mg/kg</td>
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<td>89.2</td>
<td>55-105</td>
</tr>
<tr>
<td>2-Chlorophenol</td>
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<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>4.00</td>
<td>89.2</td>
<td>55-100</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>1.91</td>
<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>2.00</td>
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<td>55-100</td>
</tr>
<tr>
<td>2,4-Dinitrotoluene</td>
<td>1.94</td>
<td>0.10</td>
<td>0.33</td>
<td>mg/kg</td>
<td>2.00</td>
<td>97.2</td>
<td>65-100</td>
</tr>
<tr>
<td>N-Nitrosodi-n-propylamine</td>
<td>1.48</td>
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<td>0.33</td>
<td>mg/kg</td>
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<td>45-90</td>
</tr>
<tr>
<td>4-Nitrophenol</td>
<td>2.77</td>
<td>0.30</td>
<td>1.6</td>
<td>mg/kg</td>
<td>4.00</td>
<td>69.3</td>
<td>60-110</td>
</tr>
<tr>
<td>Pentachlorophenol</td>
<td>3.44</td>
<td>0.20</td>
<td>1.6</td>
<td>mg/kg</td>
<td>4.00</td>
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</tr>
<tr>
<td>Phenol</td>
<td>3.53</td>
<td>0.20</td>
<td>0.33</td>
<td>mg/kg</td>
<td>4.00</td>
<td>88.3</td>
<td>54-95</td>
</tr>
<tr>
<td>Pyrene</td>
<td>2.53</td>
<td>0.030</td>
<td>0.062</td>
<td>mg/kg</td>
<td>2.00</td>
<td>127</td>
<td>50-135</td>
</tr>
</tbody>
</table>

*The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.*
# Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>Reporting Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
</tr>
</thead>
</table>

## Batch AL63004 - EPA 3540C Soxhlet MS

**Prepared:** 12/01/16  **Analyzed:** 12/08/16

- **Surrogate:** 2-Fluorobiphenyl 4.00 61-1174.06 102mg/kg
- **Surrogate:** 2-Fluorophenol 4.00 50-1133.92 98.0mg/kg
- **Surrogate:** Nitrobenzene-d5 4.00 47-1233.86 96.5mg/kg
- **Surrogate:** p-Terphenyl-d14 4.00 63-1334.72 118mg/kg
- **Surrogate:** Phenol-d6 4.00 49-1193.84 96.0mg/kg
- **Surrogate:** 2,4,6-Tribromophenol 4.00 52-1294.44 111mg/kg

## Matrix Spike (AL63004-MS1)

**Source:** 16K2270-01  **Prepared:** 12/01/16  **Analyzed:** 12/08/16  **QM-05**

- **Acenaphthene** 1.80 0.40 1.2 mg/kg 2.00 ND 90.0 35-99
- **4-Chloro-3-methylphenol** ND 4.0 6.6 mg/kg 4.00 ND 55-105 U
- **2-Chlorophenol** ND 4.0 6.6 mg/kg 4.00 ND 55-100 U
- **1,4-Dichlorobenzene** ND 4.0 6.6 mg/kg 2.00 ND 55-100 U
- **2,4-Dinitrotoluene** ND 2.0 6.6 mg/kg 2.00 ND 65-100 U
- **N-Nitrosodi-n-propylamine** ND 4.0 6.6 mg/kg 2.00 ND 45-90 U
- **4-Nitrophenol** 6.86 6.0 32 mg/kg 4.00 ND 172 60-110 J
- **Pentachlorophenol** ND 4.0 32 mg/kg 4.00 ND 60-115 U
- **Phenol** 4.80 4.0 6.6 mg/kg 4.00 ND 120 55-100 J
- **Pyrene** 2.72 0.60 1.2 mg/kg 2.00 ND 136 50-135 U

- **1,2,4-Trichlorobenzene** ND 4.0 6.6 mg/kg 2.00 ND 55-95 U
- **Surrogate:** 2-Fluorobiphenyl 4.06 mg/kg 4.00 61-117
- **Surrogate:** 2-Fluorophenol 3.92 mg/kg 4.00 50-113
- **Surrogate:** Nitrobenzene-d5 3.86 mg/kg 4.00 47-123
- **Surrogate:** p-Terphenyl-d14 4.72 mg/kg 4.00 63-133
- **Surrogate:** Phenol-d6 3.84 mg/kg 4.00 49-119
- **Surrogate:** 2,4,6-Tribromophenol 4.44 mg/kg 4.00 52-129

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Notes and Definitions

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Detected but below the Reporting Limit; therefore, result is an estimated concentration, detected but not quantified (DNQ).</td>
</tr>
<tr>
<td>QM-01</td>
<td>The spike recovery for this QC sample is outside of established control limits possibly due to a sample matrix interference.</td>
</tr>
<tr>
<td>QM-04</td>
<td>High RPD and/or poor percent recovery may reflect sample non-homogeneity.</td>
</tr>
<tr>
<td>QM-05</td>
<td>The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.</td>
</tr>
<tr>
<td>QM-07</td>
<td>The spike recovery was outside acceptance limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.</td>
</tr>
<tr>
<td>QM-4X</td>
<td>The spike recovery was outside of QC acceptance limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.</td>
</tr>
<tr>
<td>R-06</td>
<td>The Reporting Limits for this analysis have been raised to account for matrix interference.</td>
</tr>
<tr>
<td>S-06</td>
<td>The recovery of this surrogate is outside control limits due to sample dilution required from high analyte concentration and/or matrix interferences.</td>
</tr>
<tr>
<td>U</td>
<td>Analyte included in analysis, but not detected at or above MDL.</td>
</tr>
<tr>
<td>ND</td>
<td>Analyte NOT DETECTED at or above the reporting limit</td>
</tr>
<tr>
<td>dry</td>
<td>Sample results reported on a dry weight basis</td>
</tr>
<tr>
<td>MDL</td>
<td>Method detection limit</td>
</tr>
<tr>
<td>Rec</td>
<td>Recovery</td>
</tr>
<tr>
<td>RPD</td>
<td>Relative Percent Difference</td>
</tr>
</tbody>
</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
ASBESTOS TEM LABORATORIES, INC.

EPA Interim Method
Polarized Light Microscopy
Analytical Report

Laboratory Job # 345973

600 Bancroft Way, Ste. A
Berkeley, CA 94710
(510) 704-8930
FAX (510) 704-8429
www.asbestostemlabs.com

With Branch Offices Located At:
1350 FREEPORT BLVD, UNIT 104, SPARKS, NV 89431
Ph. (775) 359-3377
Dec-12-16

David S. Pingatore
Alpha Analytical Laboratories, Inc.
208 Mason Street
Ukiah, CA 95482

RE: LABORATORY JOB # 345973
Polarized light microscopy analytical results for 1 bulk sample(s).
Job Site:
Job No.: 16K2270

Enclosed please find the bulk material analytical results for one or more samples submitted for asbestos analysis. The analyses were performed in accordance with EPA Method 600/R-93/116 or 600/M4-82-020 for the determination of asbestos in bulk building materials by polarized light microscopy (PLM). Please note that while PLM analysis is commonly performed on non-friable and fine grained materials such as floor tiles and dust, the EPA method recognizes that PLM is subject to limitations. In these situations, accurate results may only be obtainable through the use of more sophisticated and accurate techniques such as transmission electron microscopy (TEM) or X-ray diffraction (XRD).

Prior to analysis, samples are logged-in and all data pertinent to the sample recorded. The samples are checked for damage or disruption of any chain-of-custody seals. A unique laboratory ID number is assigned to each sample. A hard copy log-in sheet containing all pertinent information concerning the sample is generated. This and all other relevant paper work are kept with the sample throughout the analytical procedures to assure proper analysis.

Each sample is opened in a class 100 HEPA negative air hood. A representative sampling of the material is selected and placed onto a glass microscope slide containing a drop of refractive index oil. The glass slide is placed under a polarizing light microscope where standard mineralogical techniques are used to analyze and quantify the various materials present, including asbestos. The data is then compiled into a standard report format and reviewed by the authorized signatory before being released to the client.

Sincerely Yours,

Lab Manager
ASBESTOS TEM LABORATORIES, INC.

--- These results relate only to the samples tested and must not be reproduced, except in full, with the approval of the laboratory. This report must not be used to claim product endorsement by NVLAP or any other agency of the U.S. Government. ---

Note: Test samples will be stored for three months after date of receipt, after which they will be properly disposed unless client makes other arrangements with the laboratory.
### POLARIZED LIGHT MICROSCOPY
#### ANALYTICAL REPORT
EPA Method 600/R-93/116 or 600/M4-82-020

**Contact:** David S. Pingatore  
**Address:** Alpha Analytical Laboratories, Inc.  
208 Mason Street  
Ukiah, CA 95482  
Job Site / No.  
16K2270

**Samples Indicated:** 1  
**Reg. Samples Analyzed:** 1  
**Report No.** 345973  
**Date Submitted:** Nov-29-16  
**Date Reported:** Dec-12-16

#### OTHER DATA

<table>
<thead>
<tr>
<th>SAMPLE ID</th>
<th>%</th>
<th>ASBESTOS TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
</table>
| 16K2270-01 | None Detected | 1) 10-20% Cellulose  
2) 80-90% Calc, Qtz, Other m.p. | Carpet Backing Powder  
3) 4) Dec-12-16 Debris-Off-White |
| Lab ID # 1288-01101-001 | | |
| Lab ID # | | |
| Lab ID # | | |
| Lab ID # | | |
| Lab ID # | | |
| Lab ID # | | |
| Lab ID # | | |
| Lab ID # | | |
| Lab ID # | | |

Detection Limit of Method is Estimated to be 1% Asbestos Using a Visual Area Estimation Technique

**Report No.** 345973  
**Date Submitted:** Nov-29-16  
**Date Reported:** Dec-12-16

**ASBESTOS TEM LABORATORIES, INC.**  
600 Bancroft Way, Ste. A, Berkeley CA 94710  
(510) 704-8930  
With Offices in Reno, NV (775) 359-3377  
www.asbestostemlabs.com

**Analyst**
# SUBCONTRACT ORDER

## Alpha Analytical Laboratories, Inc.

### SENDING LABORATORY:
- **Address:** 208 Mason St.
- **City:** Ukiah
- **State:** CA
- **Zip Code:** 95482
- **Phone:** (707) 468-0401
- **Fax:** (707) 468-5267
- **Project Manager:** David S. Pingatore

### RECEIVING LABORATORY:
- **Address:** 630 Bancroft Way
- **City:** Berkeley
- **State:** CA
- **Zip Code:** 94710
- **Phone:** (510) 704-8930
- **Fax:** (510) 704-8429

### Terms:
- Net 30

---

## Analysis

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Description</th>
<th>Sampled</th>
<th>Due Date</th>
<th>Expires</th>
<th>Comments</th>
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<tbody>
<tr>
<td>16K2270-01</td>
<td>Carpet Backing Powder [Soil]</td>
<td>11/23/16</td>
<td>12/12/16</td>
<td>05/22/17</td>
<td>Grind &amp; Pulvize as needed</td>
</tr>
</tbody>
</table>

**Containers Supplied:**
- 4 oz. Jar (1)

**Report to State**
- [ ]

**System Name:**
- [ ]

**User ID:**
- [ ]

**System Number:**
- [ ]

---

**WAC:**
- [ ]

**Excel:**
- [ ]

**J-Flags:**
- [ ]

---

**Released By:** [Signature]  11/23/16  
**Date:**
**Received By:** [Signature]  1/1/16  
**Date:**

**Released By**  
**Date:**
**Received By**  
**Date:**

---
WORK ORDER NUMBER: 16-11-2409

The difference is service

Eurofins Calscience, Inc. (Calscience) certifies that the test results provided in this report meet all NELAC requirements for parameters for which accreditation is required or available. Any exceptions to NELAC requirements are noted in the case narrative. The original report of subcontracted analyses, if any, is attached to this report. The results in this report are limited to the sample(s) tested and any reproduction thereof must be made in its entirety. The client or recipient of this report is specifically prohibited from making material changes to said report and, to the extent that such changes are made, Calscience is not responsible, legally or otherwise. The client or recipient agrees to indemnify Calscience for any defense to any litigation which may arise.
<table>
<thead>
<tr>
<th></th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Work Order Narrative.</td>
</tr>
<tr>
<td>2</td>
<td>Sample Summary.</td>
</tr>
<tr>
<td>3</td>
<td>Client Sample Data.</td>
</tr>
<tr>
<td></td>
<td>3.1 EPA 7199/3060A Chromium VI (Solid).</td>
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<td></td>
<td>3.2 DHS LUFT Organic Lead (Solid).</td>
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<td>4</td>
<td>Quality Control Sample Data.</td>
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<tr>
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<td>4.1 MS/MSD.</td>
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<td>4.2 LCS/LCSD.</td>
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<td>5</td>
<td>Sample Analysis Summary.</td>
</tr>
<tr>
<td>6</td>
<td>Glossary of Terms and Qualifiers.</td>
</tr>
<tr>
<td>7</td>
<td>Chain-of-Custody/Sample Receipt Form.</td>
</tr>
</tbody>
</table>
Condition Upon Receipt:

Samples were received under Chain-of-Custody (COC) on 11/29/16. They were assigned to Work Order 16-11-2409.

Unless otherwise noted on the Sample Receiving forms all samples were received in good condition and within the recommended EPA temperature criteria for the methods noted on the COC. The COC and Sample Receiving Documents are integral elements of the analytical report and are presented at the back of the report.

Holding Times:

All samples were analyzed within prescribed holding times (HT) and/or in accordance with the Calscience Sample Acceptance Policy unless otherwise noted in the analytical report and/or comprehensive case narrative, if required.

Any parameter identified in 40CFR Part 136.3 Table II that is designated as "analyze immediately" with a holding time of <= 15 minutes (40CFR-136.3 Table II, footnote 4), is considered a "field" test and the reported results will be qualified as being received outside of the stated holding time unless received at the laboratory within 15 minutes of the collection time.

Quality Control:

All quality control parameters (QC) were within established control limits except where noted in the QC summary forms or described further within this report.

Subcontractor Information:

Unless otherwise noted below (or on the subcontract form), no samples were subcontracted.

Additional Comments:

Air - Sorbent-extracted air methods (EPA TO-4A, EPA TO-10, EPA TO-13A, EPA TO-17): Analytical results are converted from mass/sample basis to mass/volume basis using client-supplied air volumes.

Solid - Unless otherwise indicated, solid sample data is reported on a wet weight basis, not corrected for % moisture. All QC results are always reported on a wet weight basis.
## Sample Summary

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Lab Number</th>
<th>Collection Date and Time</th>
<th>Number of Containers</th>
<th>Matrix</th>
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<tbody>
<tr>
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<td>16-11-2409-1</td>
<td>11/23/16 09:00</td>
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<td>Solid</td>
</tr>
</tbody>
</table>

**Client:** Alpha Analytical Laboratories, Inc.  
208 Mason St.  
Ukiah, CA 95482-4407

**Work Order:** 16-11-2409  
**Project Name:** 16K2270  
**PO Number:**  
**Date/Time Received:** 11/29/16 10:30  
**Number of Containers:** 2  

**Attn:** David Pingatore
<table>
<thead>
<tr>
<th>Client Sample Number</th>
<th>Lab Sample Number</th>
<th>Date/Time Collected</th>
<th>Matrix</th>
<th>Instrument</th>
<th>Date Prepared</th>
<th>Date/Time Analyzed</th>
<th>QC Batch ID</th>
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<td>16-11-2409-1-B</td>
<td>11/23/16 09:00</td>
<td>Solid</td>
<td>IC 11</td>
<td>11/30/16</td>
<td>11/30/16 17:16</td>
<td>161130L01P</td>
</tr>
<tr>
<td>Parameter</td>
<td>Result</td>
<td>RL</td>
<td>DF</td>
<td>Qualifiers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium, Hexavalent</td>
<td>ND</td>
<td>400</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Method Blank         | 099-05-125-2982   | N/A                 | Solid  | IC 11      | 11/30/16      | 11/30/16 16:59   | 161130L01P    |
| Parameter            | Result            | RL                  | DF     | Qualifiers |
| Chromium, Hexavalent | ND                | 400                 | 1.00   |            |
### Analytical Report

**Client:** Alpha Analytical Laboratories, Inc.  
**Address:** 208 Mason St.  
**City/State:** Ukiah, CA 95482-4407  
**Phone:** TEL: (714) 895-5494  
**Fax:** FAX: (714) 894-7501  
**Date Received:** 11/29/16  
**Work Order:** 16-11-2409  
**Preparation:** DHS LUFT  
**Method:** DHS LUFT  
**Units:** mg/kg  
**Project:** 16K2270

<table>
<thead>
<tr>
<th>Client Sample Number</th>
<th>Lab Sample Number</th>
<th>Date/Time Collected</th>
<th>Matrix</th>
<th>Instrument</th>
<th>Date Prepared</th>
<th>Date/Time Analyzed</th>
<th>QC Batch ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpet Backing Powder</td>
<td>16-11-2409-1-A</td>
<td>11/23/16 09:00</td>
<td>Solid</td>
<td>FLAA3</td>
<td>11/30/16</td>
<td>11/30/16 14:47</td>
<td>161130L01</td>
</tr>
</tbody>
</table>

**Comment(s):** The reporting limit is elevated resulting from matrix interference.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result</th>
<th>RL</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Lead</td>
<td>ND</td>
<td>2.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

| Method Blank    | 099-10-020-1949 | N/A | Solid | FLAA3 | 11/30/16 | 11/30/16 14:47 | 161130L01 |

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result</th>
<th>RL</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Lead</td>
<td>ND</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**RL:** Reporting Limit. **DF:** Dilution Factor. **MDL:** Method Detection Limit.
<table>
<thead>
<tr>
<th>Quality Control Sample ID</th>
<th>Type</th>
<th>Matrix</th>
<th>Instrument</th>
<th>Date Prepared</th>
<th>Date Analyzed</th>
<th>MS/MSD Batch Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpet Backing Powder Sample</td>
<td>Solid</td>
<td>IC 11</td>
<td>11/30/16</td>
<td>11/30/16 17:16</td>
<td>161130S01P</td>
<td></td>
</tr>
<tr>
<td>Carpet Backing Powder Matrix Spike</td>
<td>Solid</td>
<td>IC 11</td>
<td>11/30/16</td>
<td>11/30/16 17:34</td>
<td>161130S01P</td>
<td></td>
</tr>
<tr>
<td>Carpet Backing Powder Matrix Spike Duplicate</td>
<td>Solid</td>
<td>IC 11</td>
<td>11/30/16</td>
<td>11/30/16 17:43</td>
<td>161130S01P</td>
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</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample Conc.</th>
<th>Spike Conc.</th>
<th>MS Conc.</th>
<th>MS %Rec.</th>
<th>MSD Conc.</th>
<th>MSD %Rec.</th>
<th>%Rec. CL</th>
<th>RPD</th>
<th>RPD CL</th>
<th>Qualifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium, Hexavalent</td>
<td>ND</td>
<td>20000</td>
<td>9147</td>
<td>46</td>
<td>8206</td>
<td>41</td>
<td>75-125</td>
<td>11</td>
<td>0-25</td>
<td>3</td>
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</table>

RPD: Relative Percent Difference.  CL: Control Limits
<table>
<thead>
<tr>
<th>Quality Control Sample ID</th>
<th>Type</th>
<th>Matrix</th>
<th>Instrument</th>
<th>Date Prepared</th>
<th>Date Analyzed</th>
<th>MS/MSD Batch Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpet Backing Powder</td>
<td>Sample</td>
<td>Solid</td>
<td>FLAA3</td>
<td>11/30/16</td>
<td>11/30/16 14:47</td>
<td>161130S01</td>
</tr>
<tr>
<td>Carpet Backing Powder</td>
<td>Matrix Spike</td>
<td>Solid</td>
<td>FLAA3</td>
<td>11/30/16</td>
<td>11/30/16 14:47</td>
<td>161130S01</td>
</tr>
<tr>
<td>Carpet Backing Powder</td>
<td>Matrix Spike Duplicate</td>
<td>Solid</td>
<td>FLAA3</td>
<td>11/30/16</td>
<td>11/30/16 14:47</td>
<td>161130S01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample Conc.</th>
<th>Added Conc.</th>
<th>MS Conc.</th>
<th>%Rec.</th>
<th>MS Conc.</th>
<th>%Rec.</th>
<th>MSD Conc.</th>
<th>%Rec.</th>
<th>MSD Conc.</th>
<th>%Rec.</th>
<th>CL</th>
<th>RPD</th>
<th>RPD CL</th>
<th>Qualifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Lead</td>
<td>ND</td>
<td>50.00</td>
<td>64.18</td>
<td>128</td>
<td>60.48</td>
<td>121</td>
<td>22-148</td>
<td>6</td>
<td>0-18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RPD: Relative Percent Difference.  CL: Control Limits
## Quality Control - LCS

### Alpha Analytical Laboratories, Inc.

208 Mason St.
Ukiah, CA 95482-4407

**Project:** 16K2270

<table>
<thead>
<tr>
<th>Quality Control Sample ID</th>
<th>Type</th>
<th>Matrix</th>
<th>Instrument</th>
<th>Date Prepared</th>
<th>Date Analyzed</th>
<th>LCS Batch Number</th>
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<tbody>
<tr>
<td>099-05-125-2982</td>
<td>LCS</td>
<td>Solid</td>
<td>IC 11</td>
<td>11/30/16</td>
<td>11/30/16 17:07</td>
<td>161130L01P</td>
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</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Spike Added</th>
<th>Conc. Recovered</th>
<th>LCS %Rec.</th>
<th>%Rec. CL</th>
<th>Qualifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium, Hexavalent</td>
<td>20000</td>
<td>21090</td>
<td>105</td>
<td>80-120</td>
<td></td>
</tr>
</tbody>
</table>

**RPD:** Relative Percent Difference  
**CL:** Control Limits

---

**Alpha Analytical Laboratories, Inc.**

7440 Lincoln Way, Garden Grove, CA 92841-1427  
TEL: (714) 895-5494  
FAX: (714) 894-7501
### Quality Control Sample ID Type Matrix Instrument Date Prepared Date Analyzed LCS Batch Number

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Matrix</th>
<th>Instrument</th>
<th>Date Prepared</th>
<th>Date Analyzed</th>
<th>LCS Batch Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Lead</td>
<td>LCS</td>
<td>Solid</td>
<td>FLAA3</td>
<td>11/30/16</td>
<td>11/30/16 14:47</td>
<td>161130L01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Spike Added</th>
<th>Conc. Recovered</th>
<th>LCS %Rec.</th>
<th>%Rec. CL</th>
<th>Qualifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Lead</td>
<td>25.00</td>
<td>25.30</td>
<td>101</td>
<td>72-126</td>
<td></td>
</tr>
</tbody>
</table>

RPD: Relative Percent Difference. CL: Control Limits
<table>
<thead>
<tr>
<th>Method</th>
<th>Extraction</th>
<th>Chemist ID</th>
<th>Instrument</th>
<th>Analytical Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHS LUFT</td>
<td>DHS LUFT</td>
<td>309</td>
<td>FLAA3</td>
<td>1</td>
</tr>
<tr>
<td>EPA 7199</td>
<td>EPA 3060A</td>
<td>1037</td>
<td>IC 11</td>
<td>1</td>
</tr>
</tbody>
</table>

Location 1: 7440 Lincoln Way, Garden Grove, CA 92841
## Glossary of Terms and Qualifiers

### Qualifiers | Definition
--- | ---
* | See applicable analysis comment.
< | Less than the indicated value.
> | Greater than the indicated value.
1 | Surrogate compound recovery was out of control due to a required sample dilution. Therefore, the sample data was reported without further clarification.
2 | Surrogate compound recovery was out of control due to matrix interference. The associated method blank surrogate spike compound was in control and, therefore, the sample data was reported without further clarification.
3 | Recovery of the Matrix Spike (MS) or Matrix Spike Duplicate (MSD) compound was out of control due to suspected matrix interference. The associated LCS recovery was in control.
4 | The MS/MSD RPD was out of control due to suspected matrix interference.
5 | The PDS/PDSD or PES/PESD associated with this batch of samples was out of control due to suspected matrix interference.
6 | Surrogate recovery below the acceptance limit.
7 | Surrogate recovery above the acceptance limit.
B | Analyte was present in the associated method blank.
BU | Sample analyzed after holding time expired.
BV | Sample received after holding time expired.
CI | See case narrative.
E | Concentration exceeds the calibration range.
ET | Sample was extracted past end of recommended max. holding time.
HD | The chromatographic pattern was inconsistent with the profile of the reference fuel standard.
HDL | The sample chromatographic pattern for TPH matches the chromatographic pattern of the specified standard but heavier hydrocarbons were also present (or detected).
HDH | The sample chromatographic pattern for TPH matches the chromatographic pattern of the specified standard but lighter hydrocarbons were also present (or detected).
J | Analyte was detected at a concentration below the reporting limit and above the laboratory method detection limit. Reported value is estimated.
JA | Analyte positively identified but quantitation is an estimate.
ME | LCS Recovery Percentage is within Marginal Exceedance (ME) Control Limit range (+/- 4 SD from the mean).
ND | Parameter not detected at the indicated reporting limit.
Q | Spike recovery and RPD control limits do not apply resulting from the parameter concentration in the sample exceeding the spike concentration by a factor of four or greater.
SG | The sample extract was subjected to Silica Gel treatment prior to analysis.
X | % Recovery and/or RPD out-of-range.
Z | Analyte presence was not confirmed by second column or GC/MS analysis.

Solid - Unless otherwise indicated, solid sample data is reported on a wet weight basis, not corrected for % moisture. All QC results are reported on a wet weight basis.

Any parameter identified in 40CFR Part 136.3 Table II that is designated as "analyze immediately" with a holding time of <= 15 minutes (40CFR-136.3 Table II, footnote 4), is considered a "field" test and the reported results will be qualified as being received outside of the stated holding time unless received at the laboratory within 15 minutes of the collection time.

A calculated total result (Example: Total Pesticides) is the summation of each component concentration and/or, if "J" flags are reported, estimated concentration. Component concentrations showing not detected (ND) are summed into the calculated total result as zero concentrations.
### Analysis

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Description</th>
<th>Due</th>
<th>Expires</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>16K2270-01</td>
<td>Carpet Backing Powder</td>
<td></td>
<td></td>
<td>Grind &amp; pulverize as needed</td>
</tr>
<tr>
<td>Cr6 7199 Soil IC SUB</td>
<td></td>
<td>12/12/16 12:00</td>
<td>12/21/16 09:00</td>
<td></td>
</tr>
<tr>
<td>Organic Lead SUB</td>
<td></td>
<td>12/12/16 12:00</td>
<td>12/07/16 09:00</td>
<td></td>
</tr>
</tbody>
</table>

**Containers Supplied:**
- 4 oz. jar (G)
- 4 oz. jar (H)

☐ Report to State

**System Name:**

**Employed by:**

**User ID:**

**Sampler:**

**System Number:**

W/ QC
J. Fless
Excel

---

Released By: [Signature]  
Date: 11/28/16

Received By: [Signature]  
Date: 11/29/16 10:30
OnTrac 800.334.5000 ontrac.com

Waybill

2. FROM (Company):

ALPHA ANALYTICAL LAB

Street Address:

208 MASON STREET

City:

UKIAH

State ZIP Code Phone Number

CA 95482 - (707) 468-0401

3. TO (Consignee): WE CAN'T SHIP TO PO BOX OR FL FLUSH

CAL SCIENCE

Street Address:

7440 LINCOLN

City:

GARDEN GROVE

State ZIP Code Phone Number

CA 92841 - 744-095-9494

Recipient's Name

SAMPLE RECEIVING

4. Shipper's Reference Number

5. WEIGHT SUBJECT TO VERIFICATION

LBS

6. COLLECT ON DELIVERY $15.00 MINIMUM. PLEASE ATTACH DEPOSIT. ADDITIONAL CHARGES APPLY.

7. SERVICE LEVEL DEFAULT TRUCKTRAY MAY APPLY

8. SERVICE OPTIONS

Signature Required

9. DECLARED VALUE ADDITIONAL CHARGE APPLIES: LIABILITY LIMITED TO $1000 UNLESS DECLARED.

10. PAYMENT 

$100.00

OnTrac Use Driver Number / P/U Time / Initials

H H M M A/P

Shipment Originated By: OnTrac

Pre-Print Number: 236345

Shipper's Signature

Recipient Copy

See ontrac.com for terms and conditions.
**SAMPLE RECEIPT CHECKLIST**

**CLIENT:** Alpha

**DATE:** 11/29/2016

**TEMPERATURE:** (Criteria: 0.0°C – 6.0°C, not frozen except sediment/tissue)

- Thermometer ID: SC3A (CF: 0.0°C); Temperature (w/o CF): 2.9 °C (w/ CF): 2.9 °C
- Sample(s) outside temperature criteria (PM/APM contacted by: __________)
- Sample(s) outside temperature criteria but received on ice/chilled on same day of sampling
- Sample(s) received at ambient temperature; placed on ice for transport by courier

Ambient Temperature: [ ] Air  [ ] Filter

Checked by: __________

**CUSTODY SEAL:**

- Cooler [ ] Present and Intact  [ ] Present but Not Intact  [ ] Not Present  [ ] N/A
- Sample(s) [ ] Present and Intact  [ ] Present but Not Intact  [ ] Not Present  [ ] N/A

Checked by: __________

**SAMPLE CONDITION:**

- Chain-of-Custody (COC) document(s) received with samples: [ ] Yes  [ ] No  [ ] N/A
- COC document(s) received complete: __________
- Sampling date  [ ] 11/24/16
- Sampling time  [ ] 11:24:06
- Matrix: __________
- Number of containers: __________
- No analysis requested: [ ]
- Not relinquished: [ ]
- No relinquished date: [ ]
- No relinquished time: [ ]

Sampler's name indicated on COC: [ ]

Sample container label(s) consistent with COC: [ ]

Sample container(s) intact and in good condition: [ ]

Proper containers for analyses requested: [ ]

Sufficient volume/mass for analyses requested: [ ]

Samples received within holding time: [ ]

Aqueous samples for certain analyses received within 15-minute holding time:
- pH: [ ]
- Residual Chlorine: [ ]
- Dissolved Sulfide: [ ]
- Dissolved Oxygen: [ ]

Proper preservation chemical(s) noted on COC and/or sample container: [ ]

Unpreserved aqueous sample(s) received for certain analyses:
- Volatile Organics: [ ]
- Total Metals: [ ]
- Dissolved Metals: [ ]

Container(s) for certain analysis free of headspace:
- Volatile Organics: [ ]
- Dissolved Gases (RSK-175): [ ]
- Dissolved Oxygen (SM 4500): [ ]
- Carbon Dioxide (SM 4500): [ ]
- Ferrous Iron (SM 3500): [ ]
- Hydrogen Sulfide (Hach): [ ]

Tedlar™ bag(s) free of condensation: [ ]

**CONTAINER TYPE:**

(Trip Blank Lot Number: __________)

**Aqueous:**
- □ VOA
- □ VOAh
- □ VOAna
- □ 100PJ
- □ 100PJa
- □ 125AGB
- □ 125AGBh
- □ 125AGBp
- □ 125PB
- □ 125PBzna
- □ 250AGB
- □ 250CGB
- □ 250CGBs
- □ 250PB
- □ 250Pbn
- □ 500AGB
- □ 500AGJ
- □ 500AGJs
- □ 500PB
- □ 1AGB
- □ 1AGBna
- □ 1AGBs
- □ 1PB
- □ 1PBNa
- □ EnvCores®
- □ TerraCores®
- □ Other Matrix

**Solid:**
- □ 4ozCGJ
- □ 8ozCGJ
- □ 16ozCGJ
- □ Sleeve (____)
- □ Canister
- □ Sorbent Tube
- □ PUF
- □ Other Matrix (______): [ ]

**Air:**

Labeled/Checked by: __________

Reviewed by: __________

**Container:**
- □ Amber
- □ Bottle
- □ Clear
- □ Envelope
- □ Glass
- □ Jar
- □ Plastic
- □ Ziploc/Resealable Bag

**Preservative:**
- □ buffered
- □ filtered
- □ HCl
- □ HNO3
- □ NaOH
- □ Na2S2O3
- □ H3PO4
- □ H2SO4
- □ ultra-pure
- □ Na2SO4+NaHSO4
- □ Zn
- □ Zn (CH3CO3)2 + NaOH

2016-09-23 Revision
Analytical Report

WorkOrder: 1611C77

Report Created for: Alpha Analytical Laboratories
208 Mason Street
Ukiah, CA 95482

Project Contact: David S. Pingatore
Project P.O.: 16K2270
Project Name: 16K2270
Project Received: 11/29/2016

Analytical Report reviewed & approved for release on 12/05/2016 by:

[Signature]

Angela Rydelius,
Laboratory Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in the case narrative.
# Glossary of Terms & Qualifier Definitions

**Client:** Alpha Analytical Laboratories  
**Project:** 16K2270  
**WorkOrder:** 1611C77

## Glossary Abbreviation

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>%D</td>
<td>Serial Dilution Percent Difference</td>
</tr>
<tr>
<td>95% Interval</td>
<td>95% Confident Interval</td>
</tr>
<tr>
<td>DF</td>
<td>Dilution Factor</td>
</tr>
<tr>
<td>DI WET</td>
<td>(DISTLC) Waste Extraction Test using DI water</td>
</tr>
<tr>
<td>DISS</td>
<td>Dissolved (direct analysis of 0.45 µm filtered and acidified water sample)</td>
</tr>
<tr>
<td>DLT</td>
<td>Dilution Test (Serial Dilution)</td>
</tr>
<tr>
<td>DUP</td>
<td>Duplicate</td>
</tr>
<tr>
<td>EDL</td>
<td>Estimated Detection Limit</td>
</tr>
<tr>
<td>ITEF</td>
<td>International Toxicity Equivalence Factor</td>
</tr>
<tr>
<td>LCS</td>
<td>Laboratory Control Sample</td>
</tr>
<tr>
<td>MB</td>
<td>Method Blank</td>
</tr>
<tr>
<td>MB % Rec</td>
<td>% Recovery of Surrogate in Method Blank, if applicable</td>
</tr>
<tr>
<td>MDL</td>
<td>Method Detection Limit</td>
</tr>
<tr>
<td>ML</td>
<td>Minimum Level of Quantitation</td>
</tr>
<tr>
<td>MS</td>
<td>Matrix Spike</td>
</tr>
<tr>
<td>MSD</td>
<td>Matrix Spike Duplicate</td>
</tr>
<tr>
<td>N/A</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>ND</td>
<td>Not detected at or above the indicated MDL or RL</td>
</tr>
<tr>
<td>NR</td>
<td>Data Not Reported due to matrix interference or insufficient sample amount.</td>
</tr>
<tr>
<td>PDS</td>
<td>Post Digestion Spike</td>
</tr>
<tr>
<td>PDS D</td>
<td>Post Digestion Spike Duplicate</td>
</tr>
<tr>
<td>PF</td>
<td>Prep Factor</td>
</tr>
<tr>
<td>RD</td>
<td>Relative Difference</td>
</tr>
<tr>
<td>RL</td>
<td>Reporting Limit (The RL is the lowest calibration standard in a multipoint calibration.)</td>
</tr>
<tr>
<td>RPD</td>
<td>Relative Percent Deviation</td>
</tr>
<tr>
<td>RRT</td>
<td>Relative Retention Time</td>
</tr>
<tr>
<td>SPK Val</td>
<td>Spike Value</td>
</tr>
<tr>
<td>SPK Ref Val</td>
<td>Spike Reference Value</td>
</tr>
<tr>
<td>SPLP</td>
<td>Synthetic Precipitation Leachate Procedure</td>
</tr>
<tr>
<td>ST</td>
<td>Sorbent Tube</td>
</tr>
<tr>
<td>TCLP</td>
<td>Toxicity Characteristic Leachate Procedure</td>
</tr>
<tr>
<td>TEQ</td>
<td>Toxicity Equivalents</td>
</tr>
<tr>
<td>WET (STLC)</td>
<td>Waste Extraction Test (Soluble Threshold Limit Concentration)</td>
</tr>
</tbody>
</table>
## Analytical Report

**Client:** Alpha Analytical Laboratories  
**WorkOrder:** 1611C77  
**Date Received:** 11/29/16 10:56  
**Date Prepared:** 12/5/16  
**Project:** 16K2270  
**Extraction Method:** SW3050B  
**Analytical Method:** SW6010B  
**Unit:** mg/kg

### Sulfur

<table>
<thead>
<tr>
<th>Client ID</th>
<th>Lab ID</th>
<th>Matrix</th>
<th>Date Collected</th>
<th>Instrument</th>
<th>Batch ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpet Backing Powder</td>
<td>1611C77-001A</td>
<td>Solid</td>
<td>11/23/2016 09:00</td>
<td>ICP-JY</td>
<td>130515</td>
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<th>Result</th>
<th>MDL</th>
<th>RL</th>
<th>DF</th>
<th>Date Analyzed</th>
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<tbody>
<tr>
<td>Sulfur</td>
<td>2600</td>
<td>30</td>
<td>30</td>
<td>2</td>
<td>12/05/2016 17:04</td>
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</tbody>
</table>

**Analyst(s):** BBO  

---  

Angela Rydelius, Lab Manager

CDPH ELAP 1644 • NELAP 4033ORELAP
Quality Control Report

Client: Alpha Analytical Laboratories
WorkOrder: 1611C77
Date Prepared: 12/5/16
BatchID: 130515
Date Analyzed: 12/5/16
Extraction Method: SW3050B
Instrument: ICP-JY
Analytical Method: SW6010B
Matrix: Soil
Sample ID: MB/LCS-130515
Project: 16K2270

1611C77-001AMS/MSD

QC Summary Report for Sulfur

<table>
<thead>
<tr>
<th>Analyte</th>
<th>MB Result</th>
<th>LCS Result</th>
<th>MDL</th>
<th>RL</th>
<th>SPK Val</th>
<th>MB SS %REC</th>
<th>LCS %REC</th>
<th>LCS Limits</th>
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<tbody>
<tr>
<td>Sulfur</td>
<td>ND</td>
<td>254</td>
<td>15</td>
<td>15</td>
<td>250</td>
<td>-</td>
<td>102</td>
<td>75-125</td>
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<table>
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<tr>
<th>Analyte</th>
<th>MS Result</th>
<th>MSD Result</th>
<th>SPK Val</th>
<th>SPKRef Val</th>
<th>MS %REC</th>
<th>MSD %REC</th>
<th>MS/MSD Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
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<tbody>
<tr>
<td>Sulfur</td>
<td>NR</td>
<td>NR</td>
<td>250</td>
<td>2570</td>
<td>NR</td>
<td>NR</td>
<td>75-125</td>
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</table>

CDPH ELAP 1644 • NELAP 4033ORELAP

QA/QC Officer
Report to:
David S. Pingatore
Alpha Analytical Laboratories
208 Mason Street
Ukiah, CA 95482
(707) 468-0401

Email: sspeaks@alpha-labs.com; david@alpha-la
cc/3rd Party: 

Bill to:
Accounts Payable
Alpha Analytical Laboratories
208 Mason Street
Ukiah, CA 95482

Requested TAT: 5 days;

Date Received: 11/29/2016
Date Logged: 11/30/2016

Lab ID: 1611C77-001
Matrix: Carpet Backing Powder
Collection Date: 11/23/2016 09:00
Hold: A

Requested Tests (See legend below)

<table>
<thead>
<tr>
<th>Test Legend</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>SULFUR_TTLCS</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
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<td>2</td>
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<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Prepared by: Maria Venegas

Comments:

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days).
Hazardous samples will be returned to client or disposed of at client expense.
WORK ORDER SUMMARY

Client Name: ALPHA ANALYTICAL LABORATORIES  Project: 16K2270
Client Contact: David S. Pingatore  Comments:
Contact's Email: sspeaks@alpha-labs.com;david@alpha-labs.com; lquinn@alpha-labs.com

<table>
<thead>
<tr>
<th>Lab ID</th>
<th>Client ID</th>
<th>Matrix</th>
<th>Test Name</th>
<th>Containers /Composites</th>
<th>Bottle &amp; Preservative</th>
<th>De-chlorinated</th>
<th>Collection Date &amp; Time</th>
<th>TAT</th>
<th>Sediment Content</th>
<th>Hold</th>
<th>SubOut</th>
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</thead>
<tbody>
<tr>
<td>1611C77-001A</td>
<td></td>
<td>Solid</td>
<td>SW6010B (Sulfur)</td>
<td>1</td>
<td>4OZ GJ</td>
<td>11/23/2016 9:00</td>
<td>5 days</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

NOTES: - STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).

- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.
**SUBCONTRACT ORDER**

Alpha Analytical Laboratories, Inc.

16K2270

<table>
<thead>
<tr>
<th>SENDING LABORATORY:</th>
<th>RECEIVING LABORATORY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha Analytical Laboratories, Inc.</td>
<td>McCampbell Analytical</td>
</tr>
<tr>
<td>208 Mason St.</td>
<td>1534 Willowpass Rd.</td>
</tr>
<tr>
<td>Ukiah, CA 95482</td>
<td>Pittsburg, CA 94565</td>
</tr>
<tr>
<td>Phone: (707)468-0401</td>
<td>Phone: (925) 252-9262</td>
</tr>
<tr>
<td>Fax: (707)468-5267</td>
<td>Fax: (925) 252-9269</td>
</tr>
<tr>
<td>Project Manager: David S. Pingatore</td>
<td>Terms: Net 30</td>
</tr>
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</table>

### Analysis

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Due</th>
<th>Expires</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>16K2270-01 Carpet Backing Powder [Soil] Sampled 11/23/16 09:00 Pacific</td>
<td></td>
<td></td>
<td>Grind &amp; pulverize as needed</td>
</tr>
<tr>
<td>S Total ICP 6010</td>
<td>12/12/16 12:00</td>
<td>05/22/17 09:00</td>
<td></td>
</tr>
</tbody>
</table>

*Containers Supplied:*
- 4 oz. jar (F)

☐ Report to State

<table>
<thead>
<tr>
<th>System Name:</th>
<th>Employed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>User ID:</td>
<td>Sampler:</td>
</tr>
</tbody>
</table>

System Number: __________________

W/QC

J Flags

Excel

Released By: [Signature] Date: 11/20/16

Received By: [Signature] Date: 11/20/16 1056

Tracking Number: B10325092301
<table>
<thead>
<tr>
<th>Description</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample Receipt Information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Custody seals intact on shipping container/cooler?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Shipping container/cooler in good condition?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Samples in proper containers/bottles?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Sample containers intact?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Sufficient sample volume for indicated test?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>Sample Preservation and Hold Time (HT) Information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All samples received within holding time?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Sample/Temp Blank temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water - VOA vials have zero headspace / no bubbles?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Sample labels checked for correct preservation?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>pH acceptable upon receipt (Metal: &lt;2; 522: &lt;4; 218.7: &gt;8)?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Samples Received on Ice?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>UCMR3 Samples:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Chlorine tested and acceptable upon receipt for EPA 522?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Free Chlorine tested and acceptable upon receipt for EPA 218.7, 300.1, 537, 539?</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
# Chain of Custody - Work Order

Reports and Invoices delivered by email in PDF format

**Lab No:** 10K2270  
**Pg.** of

## Company Information
- **Company:** Humboldt State University  
- **Contact:** Brad Finney  
- **Address:** Environmental Resources & Engineering  
  1 Harpsett Street, Arcata CA 95521  
- **Phone/Fax:** 707-826-3918  
- **Email Address:** brad.finney@humboldt.edu

## Sample Information
- **Sample Identification:** Carpet Backing Powder  
  - **Date:** 11/23  
  - **Time:** 9:08

## Analysis Request
### Container
- 40m Vial
- Poly
- Glass
- Sleeve
- Other
- HCl
- HNO3
- H2SO4
- Other
- None
- Water
- Soil
- Other

### Preservation
- Ammonia, Chloride, Fluoride, Orthophosphate
- Total Nitrogen Calc
- NO3 as NO2 as N, TKN
- Asbestos - Bulk (sub)
- Organic Lead (sub)
- Sulfur 8010 (sub)
- Flag Sample, MDL reporting
- Standard Excel EDD format

### Laboratory Instructions
- Grind & Pulverize the matrix as needed prior to TTL extract

## Signature
- **Signature:** BRAD FINNEY

## CDPH Write On EDT Transmission?
- **Yes**
- **No**

## State System Number
- If "Y" please enter the Source Number(s) in the column above
Carpet Backing Powder - Leachate Results
ELAP Certificates 1551, 2728, and 2922

08 February 2017

Humboldt State Univ - Env. Resources & Engineering
Brad Finney
1 Harpst Street
Arcata, CA 95521
RE: Carpet Backing Leachate
Work Order: 17A2184

Enclosed are the results of analyses for samples received by the laboratory on 01/24/17 09:30. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeanette L. Poplin For David S. Pingatore
Project Manager
Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata CA, 95521

Project Manager: Brad Finney
Project: Carpet Backing Leachate
Project Number: [none]
Reported: 02/08/17 08:53

ANALYTICAL REPORT FOR SAMPLES

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Laboratory ID</th>
<th>Matrix</th>
<th>Date Sampled</th>
<th>Date Received</th>
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<tbody>
<tr>
<td>C1</td>
<td>17A2184-01</td>
<td>Water</td>
<td>01/22/17 11:00</td>
<td>01/24/17 09:30</td>
</tr>
<tr>
<td>C2</td>
<td>17A2184-02</td>
<td>Water</td>
<td>01/22/17 11:00</td>
<td>01/24/17 09:30</td>
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<td>C3</td>
<td>17A2184-03</td>
<td>Water</td>
<td>01/22/17 11:00</td>
<td>01/24/17 09:30</td>
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</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
### Metals by EPA 6000/7000 Series Methods

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Limit</th>
<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<td>02/01/17 08:07</td>
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<td>02/01/17 08:07</td>
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<td>J</td>
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<td>Molybdenium</td>
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<td>EPA 6010B</td>
<td>J</td>
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<tr>
<td>Selenium</td>
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<td>02/06/17 12:51</td>
<td>EPA 6010B</td>
<td>U</td>
</tr>
<tr>
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<td>02/06/17 12:51</td>
<td>EPA 6010B</td>
<td>U</td>
</tr>
<tr>
<td>Sodium</td>
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<td>1.0</td>
<td>mg/L</td>
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<td>02/01/17 08:07</td>
<td>02/06/17 12:51</td>
<td>EPA 6010B</td>
<td>U</td>
</tr>
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<tr>
<td>Thallium</td>
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</table>

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### Analyte and Results Table

#### Conventional Chemistry Parameters by APHA/EPA Methods

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>MDL</th>
<th>Units</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
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#### Chloride

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#### Nitrate as N

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<th>Notes</th>
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<tbody>
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#### Nitrite as N

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<th>Notes</th>
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#### Anions by EPA Method 300.0

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<th>Notes</th>
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<td>mg/L</td>
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</tr>
<tr>
<td>Fluoride</td>
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<td>0.070</td>
<td>mg/L</td>
<td>AA74288</td>
<td>01/24/17 17:56</td>
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<tr>
<td>Nitrate as N</td>
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<td>0.040</td>
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<td>Nitrite as N</td>
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<td>mg/L</td>
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#### Semivolatile Organic Compounds by EPA Method 8270C

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<th>Notes</th>
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<tr>
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<td>10 ug/L</td>
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<tr>
<td>Acenaphthylene</td>
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<tr>
<td>Anthracene</td>
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<td>0.39</td>
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<tr>
<td>Benz(a) anthracene</td>
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<td>0.39</td>
<td>10 ug/L</td>
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<tr>
<td>Benz(a) pyrene</td>
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<tr>
<td>Benzo(b) fluoranthene</td>
<td>ND</td>
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<tr>
<td>Benzo(k) fluoranthene</td>
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<td>Benzoic acid</td>
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<tr>
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<tr>
<td>Bis(2-chloroethoxy)methane</td>
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<td>Bis(2-chloroethyl)ether</td>
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<td>Bis(2-chloroisopropyl)ether</td>
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<td>Bis(2-ethylhexyl)phthalate</td>
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<tr>
<td>4-Bromophenyl phenyl ether</td>
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<td>Butyl benzyl phthalate</td>
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<td>EPA 8270C</td>
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<td>4-Chloro-3-methylphenol</td>
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<tr>
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<tr>
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<td>01/25/17 09:14</td>
<td>01/30/17 10:08</td>
<td>EPA 8270C</td>
<td>U</td>
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### Results of Analytes

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<p>| Semivolatile Organic Compounds by EPA Method 8270C |
|---|---|---|---|---|---|---|---|---|
| <strong>Analyte</strong> | <strong>Result</strong> | <strong>MDL</strong> | <strong>Units</strong> | <strong>Batch</strong> | <strong>Prepared</strong> | <strong>Analyzed</strong> | <strong>Method</strong> | <strong>Notes</strong> |
| 2-Chlorophenol | ND | 0.66 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 4-Chlorophenyl phenyl ether | ND | 0.93 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Chrysene | ND | 0.76 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Di-n-butyl phthalate | ND | 0.91 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Di-n-octyl phthalate | ND | 0.65 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Dibenz (a,h) anthracene | ND | 0.83 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Dibenzo furan | ND | 0.86 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 1,2-Dichlorobenzene | ND | 0.61 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 1,3-Dichlorobenzene | ND | 0.62 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 1,4-Dichlorobenzene | ND | 0.61 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2,4-Dichlorophenol | ND | 0.66 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| <strong>Diethyl phthalate</strong> | 6.1 | 0.86 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | J |
| Dimethyl phthalate | ND | 0.68 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2,4-Dimethylphenol | ND | 1.2 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 4,6-Dinitro-2-methylphenol | ND | 0.75 | 50 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2,4-Dinitrophenol | ND | 1.3 | 50 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2,4-Dinitrotoluene | ND | 0.68 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2,6-Dinitrotoluene | ND | 0.54 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 1,2-Diphenylhydrizine | ND | 0.60 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Fluoranthene | ND | 0.76 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Fluorene | ND | 0.81 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Hexachlorobenzene | ND | 0.89 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Hexachlorobutadiene | ND | 0.84 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Hexachloroclophene | ND | 0.45 | 15 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Hexachloroethene | ND | 0.58 | 15 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Indeno (1,2,3-cd) pyrene | ND | 0.63 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| Isophorone | ND | 0.81 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2-Methylnaphthalene | ND | 1.0 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| 2-Methylnaphthalene (o-cresol) | ND | 0.64 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| <strong>3 &amp; 4-Methylphenol (m,p-cresol)</strong> | 6.4 | 0.60 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | J |
| N-Nitrosodi-n-propylamine | ND | 0.85 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |
| N-Nitrosodimethylamine | ND | 1.1 | 5.0 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:08 | EPA 8270C | U |</p>
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<th>Result</th>
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<th>Units</th>
<th>Dilution</th>
<th>Batch</th>
<th>Prepared</th>
<th>Analyzed</th>
<th>Method</th>
<th>Notes</th>
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<td>U</td>
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<tr>
<td>Naphthalene</td>
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<td>10 ug/L</td>
<td>1</td>
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<td>01/25/17 09:14</td>
<td>01/30/17 10:08</td>
<td>EPA 8270C</td>
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<tr>
<td>2-Nitroaniline</td>
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<td>AA74331</td>
<td>01/25/17 09:14</td>
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**Analyte** | **Result** | **MDL** | **Units** | **Batch** | **Prepared** | **Analyzed** | **Method** | **Notes**
--- | --- | --- | --- | --- | --- | --- | --- | ---
Ammonia as N | ND | 0.10 | mg/L | 1 | AA74401 | 01/27/17 09:00 | 01/27/17 16:00 | SM4500NH3C | U
Silica | ND | 0.30 | mg/L | 1 | AB73025 | 02/06/17 08:30 | 02/06/17 11:30 | SM4500-SiO2 | C
Total Kjeldahl Nitrogen | 13 | 0.20 | mg/L | 1 | AA74536 | 02/01/17 06:09 | 02/01/17 10:31 | SM4500-Norg | B
Total Nitrogen | 13 | 0.20 | mg/L | 1 | AA74533 | 01/30/17 16:50 | 02/03/17 15:20 | SM4500-N | 
Chloride | 2100 | 10 | mg/L | 100 | AA74288 | 01/25/17 12:15 | 01/25/17 12:15 | EPA 300.0 | 
Fluoride | 0.50 | 0.35 | mg/L | 5 | AA74288 | 01/24/17 16:29 | 01/24/17 16:29 | EPA 300.0 | 
Nitrate as N | ND | 0.20 | mg/L | 5 | AA74288 | 01/24/17 16:29 | 01/24/17 16:29 | EPA 300.0 | R-01, T-2, U
Nitrite as N | ND | 0.10 | mg/L | 5 | AA74288 | 01/24/17 16:29 | 01/24/17 16:29 | EPA 300.0 | R-01, T-2, U
Orthophosphate | 5.1 | 0.35 | ug/L | 5 | AA74288 | 01/24/17 16:29 | 01/24/17 16:29 | EPA 300.0 | T-2

### Semivolatile Organic Compounds by EPA Method 8270C

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<th>Method</th>
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Acenaphthene | ND | 0.57 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Acenaphthylene | ND | 0.48 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Anthracene | ND | 0.39 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Benzo (a) anthracene | ND | 0.39 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Benzo (a) pyrene | ND | 0.50 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Benzo (b) fluoranthene | ND | 0.64 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Benzo (g,h,i) perylene | ND | 0.93 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Benzo (k) fluoranthene | ND | 0.34 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Benzoic acid | 24 | 12 | 50 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | J
Benzy alcohol | ND | 6.7 | 20 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Bis(2-chloroethoxy)methane | ND | 0.81 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Bis(2-chloroethyl)ether | ND | 0.30 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Bis(2-chloroisopropyl)ether | ND | 0.41 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Bis(2-ethylhexyl)phthalate | 8.0 | 0.83 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | J
4-Bromophenyl phenyl ether | ND | 0.43 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
Butyl benzyl phthalate | 3.4 | 0.64 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | J
4-Chloro-3-methylphenol | ND | 0.58 | 10 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U
4-Chloroaniline | ND | 6.2 | 20 ug/L | 1 | AA74331 | 01/25/17 09:14 | 01/30/17 10:46 | EPA 8270C | U

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Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA 95521

Project Manager: Brad Finney
Project: Carpet Backing Leachate
Project Number: [none]
Reported: 02/08/17 08:53

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Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA, 95521

Project Manager: Brad Finney
Project: Carpet Backing Leachate
Project Number: [none]
Reported: 02/08/17 08:53

C2
17A2184-02(Water)

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### Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata, CA, 95521

Project Manager: Brad Finney
Project: Carpet Backing Leachate
Project Number: [none]

Reported: 02/08/17 08:53

---

## C3

**17A2184-03(Water)**

### Conventional Chemistry Parameters by APHA/EPA Methods

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### Anions by EPA Method 300.0

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### Orthophosphate

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### Semivolatile Organic Compounds by EPA Method 8270C

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### Analytes and Results

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### Semivolatile Organic Compounds by EPA Method 8270C

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### Metals by EPA 6000/7000 Series Methods - Quality Control

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# Metals by EPA 6000/7000 Series Methods - Quality Control

## Batch AB72829 - Metals Digest

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## Metals by EPA 6000/7000 Series Methods - Quality Control

**Batch AB72829 - Metals Digest**

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**Duplicate (AB72829-DUP1)**

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Humboldt State Univ - Env. Resources & Engineering  
1 Harpst Street  
Arcata, CA, 95521  

Project Manager: Brad Finney  
Project: Carpet Backing Leachate  
Project Number: [none]  
Reported: 02/08/17 08:53  

### Metals by EPA 6000/7000 Series Methods - Quality Control

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### Metals by EPA 6000/7000 Series Methods - Quality Control

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### Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control

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<th>Source</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
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### Anions by EPA Method 300.0 - Quality Control

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Batch AA74288 - General Preparation

Matrix Spike Dup (AA74288-MSD1) | Source: 17A1268-01 | Prepared & Analyzed: 01/24/17

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### Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

**Batch AA74331 - SVOAs in Water GCMS**

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### Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

**Batch AA74331 - SVOAs in Water GCMS**

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### Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

**Batch AA74331 - SVOAs in Water GCMS**

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<th>RPD Limit</th>
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<th>Analyte</th>
<th>Result (ug/L)</th>
<th>Reporting Limit</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>%REC Limits</th>
<th>RPD Limit</th>
<th>Notes</th>
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**Semivolatile Organic Compounds by EPA Method 8270C - Quality Control**

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The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

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<th>Analyte</th>
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<th>Spike Level</th>
<th>Source Result</th>
<th>%REC</th>
<th>%REC Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
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Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

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<th>Analyte</th>
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<th>MDL</th>
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Humboldt State Univ - Env. Resources & Engineering
1 Harpst Street
Arcata CA, 95521

Project Manager: Brad Finney
Project: Carpet Backing Leachate
Project Number: [none]

Reported: 02/08/17 08:53

Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

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<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
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<th>%REC</th>
<th>RPD</th>
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### Semivolatile Organic Compounds by EPA Method 8270C - Quality Control

#### Batch AA74331 - SVOAs in Water GCMS

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<th>Limit</th>
<th>Units</th>
<th>Spike Level</th>
<th>Source</th>
<th>%REC</th>
<th>%REC Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
<th>Notes</th>
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<td>Phenol</td>
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<td>0.46</td>
<td>10</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>52.0</td>
<td>17-87</td>
<td>0.58</td>
<td>25</td>
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<tr>
<td>Pyrene</td>
<td>43.0</td>
<td>0.45</td>
<td>10</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>108</td>
<td>66-130</td>
<td>4.72</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>1,2,4-Trichlorobenzene</td>
<td>30.7</td>
<td>0.59</td>
<td>10</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>76.7</td>
<td>44-101</td>
<td>5.07</td>
<td>25</td>
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</tr>
<tr>
<td>2,4,5-Trichlorophenol</td>
<td>36.1</td>
<td>0.58</td>
<td>10</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>90.3</td>
<td>65-125</td>
<td>1.76</td>
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<tr>
<td>2,4,6-Trichlorophenol</td>
<td>38.7</td>
<td>0.74</td>
<td>10</td>
<td>ug/L</td>
<td>40.0</td>
<td>ND</td>
<td>96.8</td>
<td>69-120</td>
<td>4.44</td>
<td>25</td>
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<tr>
<td>Surrogate: 2-Fluorobiphenyl</td>
<td>33.8</td>
<td></td>
<td>ug/L</td>
<td>40.0</td>
<td>84.6</td>
<td>42-113</td>
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<td></td>
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</tr>
<tr>
<td>Surrogate: 2-Fluorophenol</td>
<td>25.9</td>
<td></td>
<td>ug/L</td>
<td>40.0</td>
<td>64.8</td>
<td>21-87</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Surrogate: Nitrobenzene-d5</td>
<td>32.7</td>
<td></td>
<td>ug/L</td>
<td>40.0</td>
<td>81.8</td>
<td>50-110</td>
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<tr>
<td>Surrogate: p-Terphenyl-d14</td>
<td>44.9</td>
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<td>ug/L</td>
<td>40.0</td>
<td>112</td>
<td>61-134</td>
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<tr>
<td>Surrogate: Phenol-d6</td>
<td>19.2</td>
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<td>ug/L</td>
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<tr>
<td>Surrogate: 2,4,6-Tribromophenol</td>
<td>38.4</td>
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<td>ug/L</td>
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<td>95.9</td>
<td>54-135</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Notes and Definitions

J  Detected but below the Reporting Limit; therefore, result is an estimated concentration, detected but not quantified (DNQ).

QM-01  The spike recovery for this QC sample is outside of established control limits possibly due to a sample matrix interference.

QM-05  The spike recovery was outside acceptance limits for the MS and/or MSD due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

QM-08  The RPD was outside acceptance limits for MS/MSD, possibly due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

QM-4X  The spike recovery was outside of QC acceptance limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

R-01  The Reporting Limit for this analyte has been raised to account for matrix interference.

T-2  Sample analyzed outside of recommended holding time per client.

U  Analyte included in analysis, but not detected at or above MDL.

ND  Analyte NOT DETECTED at or above the reporting limit

dry  Sample results reported on a dry weight basis

REC  Recovery

RPD  Relative Percent Difference

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.
Analytical Report

WorkOrder: 1701B45

Report Created for: Alpha Analytical Laboratories

208 Mason Street
Ukiah, CA 95482

Project Contact: David S. Pingatore
Project P.O.: 17A2184
Project Name: 17A2184
Project Received: 01/26/2017

Analytical Report reviewed & approved for release on 02/01/2017 by:

[Signature]

Angela Rydelius,
Laboratory Manager

The report shall not be reproduced except in full, without the written approval of the laboratory. The analytical results relate only to the items tested. Results reported conform to the most current NELAP standards, where applicable, unless otherwise stated in the case narrative.
# Glossary of Terms & Qualifier Definitions

**Client:** Alpha Analytical Laboratories  
**Project:** 17A2184  
**WorkOrder:** 1701B45

## Glossary Abbreviation

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>%D</td>
<td>Serial Dilution Percent Difference</td>
</tr>
<tr>
<td>95% Interval</td>
<td>95% Confident Interval</td>
</tr>
<tr>
<td>DF</td>
<td>Dilution Factor</td>
</tr>
<tr>
<td>DI WET</td>
<td>(DISTLC) Waste Extraction Test using DI water</td>
</tr>
<tr>
<td>DISS</td>
<td>Dissolved (direct analysis of 0.45 µm filtered and acidified water sample)</td>
</tr>
<tr>
<td>DLT</td>
<td>Dilution Test (Serial Dilution)</td>
</tr>
<tr>
<td>DUP</td>
<td>Duplicate</td>
</tr>
<tr>
<td>EDL</td>
<td>Estimated Detection Limit</td>
</tr>
<tr>
<td>ITEF</td>
<td>International Toxicity Equivalence Factor</td>
</tr>
<tr>
<td>LCS</td>
<td>Laboratory Control Sample</td>
</tr>
<tr>
<td>MB</td>
<td>Method Blank</td>
</tr>
<tr>
<td>MB % Rec</td>
<td>% Recovery of Surrogate in Method Blank, if applicable</td>
</tr>
<tr>
<td>MDL</td>
<td>Method Detection Limit</td>
</tr>
<tr>
<td>ML</td>
<td>Minimum Level of Quantitation</td>
</tr>
<tr>
<td>MS</td>
<td>Matrix Spike</td>
</tr>
<tr>
<td>MSD</td>
<td>Matrix Spike Duplicate</td>
</tr>
<tr>
<td>N/A</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>ND</td>
<td>Not detected at or above the indicated MDL or RL</td>
</tr>
<tr>
<td>NR</td>
<td>Data Not Reported due to matrix interference or insufficient sample amount.</td>
</tr>
<tr>
<td>PDS</td>
<td>Post Digestion Spike</td>
</tr>
<tr>
<td>PDS D</td>
<td>Post Digestion Spike Duplicate</td>
</tr>
<tr>
<td>PF</td>
<td>Prep Factor</td>
</tr>
<tr>
<td>RD</td>
<td>Relative Difference</td>
</tr>
<tr>
<td>RL</td>
<td>Reporting Limit (The RL is the lowest calibration standard in a multipoint calibration.)</td>
</tr>
<tr>
<td>RPD</td>
<td>Relative Percent Deviation</td>
</tr>
<tr>
<td>RRT</td>
<td>Relative Retention Time</td>
</tr>
<tr>
<td>SPK Val</td>
<td>Spike Value</td>
</tr>
<tr>
<td>SPK Ref Val</td>
<td>Spike Reference Value</td>
</tr>
<tr>
<td>SPLP</td>
<td>Synthetic Precipitation Leachate Procedure</td>
</tr>
<tr>
<td>ST</td>
<td>Sorbent Tube</td>
</tr>
<tr>
<td>TCLP</td>
<td>Toxicity Characteristic Leachate Procedure</td>
</tr>
<tr>
<td>TEQ</td>
<td>Toxicity Equivalents</td>
</tr>
<tr>
<td>WET (STLC)</td>
<td>Waste Extraction Test (Soluble Threshold Limit Concentration)</td>
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## Quality Control Qualifiers

<table>
<thead>
<tr>
<th>Qualifier</th>
<th>Definition</th>
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<tbody>
<tr>
<td>F10</td>
<td>MS/MSD outside control limits. Physical or chemical interferences exist due to sample matrix.</td>
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</table>
## Silicon

<table>
<thead>
<tr>
<th>Client ID</th>
<th>Lab ID</th>
<th>Matrix</th>
<th>Date Collected</th>
<th>Instrument</th>
<th>Batch ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1701B45-001A</td>
<td>Water</td>
<td>01/22/2017 11:00</td>
<td>ICP-JY</td>
<td>133189</td>
</tr>
<tr>
<td><strong>Analytes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Silicon</td>
<td>Result</td>
<td>MDL</td>
<td>RL</td>
<td>DF</td>
<td>Date Analyzed</td>
</tr>
<tr>
<td></td>
<td>620</td>
<td>15</td>
<td>50</td>
<td>1</td>
<td>01/31/2017 18:12</td>
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<tr>
<td><strong>Surrogates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terbium</td>
<td>REC (%)</td>
<td>Limits</td>
<td></td>
<td></td>
<td>01/31/2017 18:12</td>
</tr>
<tr>
<td><strong>Analyst(s):</strong></td>
<td>BBO</td>
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<table>
<thead>
<tr>
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<th>Lab ID</th>
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<th>Instrument</th>
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<td>C2</td>
<td>1701B45-002A</td>
<td>Water</td>
<td>01/22/2017 11:00</td>
<td>ICP-JY</td>
<td>133189</td>
</tr>
<tr>
<td><strong>Analytes</strong></td>
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</tr>
<tr>
<td>Silicon</td>
<td>Result</td>
<td>MDL</td>
<td>RL</td>
<td>DF</td>
<td>Date Analyzed</td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td>15</td>
<td>50</td>
<td>1</td>
<td>01/31/2017 18:15</td>
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<tr>
<td><strong>Surrogates</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Terbium</td>
<td>REC (%)</td>
<td>Limits</td>
<td></td>
<td></td>
<td>01/31/2017 18:15</td>
</tr>
<tr>
<td><strong>Analyst(s):</strong></td>
<td>BBO</td>
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<th>Lab ID</th>
<th>Matrix</th>
<th>Date Collected</th>
<th>Instrument</th>
<th>Batch ID</th>
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</thead>
<tbody>
<tr>
<td>C3</td>
<td>1701B45-003A</td>
<td>Water</td>
<td>01/22/2017 11:00</td>
<td>ICP-JY</td>
<td>133189</td>
</tr>
<tr>
<td><strong>Analytes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td>Result</td>
<td>MDL</td>
<td>RL</td>
<td>DF</td>
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</tr>
<tr>
<td></td>
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<td><strong>Surrogates</strong></td>
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<tr>
<td>Terbium</td>
<td>REC (%)</td>
<td>Limits</td>
<td></td>
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<td>01/31/2017 17:53</td>
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<td>BBO</td>
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</table>
**Quality Control Report**

Client: Alpha Analytical Laboratories  
WorkOrder: 1701B45  
Date Prepared: 1/26/17  
Date Analyzed: 1/31/17  
BatchID: 133189  
Instrument: ICP-JY  
Analytical Method: E200.7  
Matrix: Water  
Sample ID: MB/LCS-133189  
Project: 17A2184  

---

### QC Summary Report for Silicon

<table>
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<tr>
<th>Analyte</th>
<th>MB Result</th>
<th>LCS Result</th>
<th>MDL</th>
<th>RL</th>
<th>SPK Val</th>
<th>MB SS %REC</th>
<th>LCS %REC</th>
<th>LCS Limits</th>
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<tbody>
<tr>
<td>Silicon</td>
<td>ND</td>
<td>502</td>
<td>15</td>
<td>50</td>
<td>500</td>
<td>-</td>
<td>100</td>
<td>80-120</td>
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**Surrogate Recovery**

<table>
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<tr>
<th>Analyte</th>
<th>MS Result</th>
<th>MSD Result</th>
<th>SPK Val</th>
<th>SPKRef Val</th>
<th>MS %REC</th>
<th>MSD %REC</th>
<th>MS/MSD Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
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</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>1670</td>
<td>1580</td>
<td>500</td>
<td>1065</td>
<td>121,F10</td>
<td>104</td>
<td>80-120</td>
<td>5.22</td>
<td>20</td>
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**Surrogate Recovery**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>MS Result</th>
<th>MSD Result</th>
<th>SPK Val</th>
<th>SPKRef Val</th>
<th>MS %REC</th>
<th>MSD %REC</th>
<th>MS/MSD Limits</th>
<th>RPD</th>
<th>RPD Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terbium</td>
<td>850</td>
<td>767</td>
<td>750</td>
<td>113</td>
<td>102</td>
<td>70-130</td>
<td>10.3</td>
<td>20</td>
<td>20</td>
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### Analyte

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<tr>
<th>Analyte</th>
<th>DLT Result</th>
<th>DLTRef Val</th>
<th>%D</th>
<th>%D Limit</th>
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<tbody>
<tr>
<td>Silicon</td>
<td>1020</td>
<td>1065</td>
<td>4.23</td>
<td>-</td>
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</tbody>
</table>

% D Control Limit applied to analytes with concentrations greater than 25 times the reporting limits.
### CHAIN-OF-CUSTODY RECORD

**WorkOrder:** 1701B45  
**ClientCode:** ALPU

#### Lab ID | Client ID | Matrix | Collection Date | Hold | Requested Tests (See legend below)
--- | --- | --- | --- | --- | ---
1701B45-001 | C1 | Water | 1/22/2017 11:00 | A | 1  2  3  4  5  6  7  8  9  10  11  12
1701B45-002 | C2 | Water | 1/22/2017 11:00 | A |
1701B45-003 | C3 | Water | 1/22/2017 11:00 | A |

#### Test Legend:

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<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SI_TTLC_W</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

#### Comments:

NOTE: Soil samples are discarded 60 days after results are reported unless other arrangements are made (Water samples are 30 days). Hazardous samples will be returned to client or disposed of at client expense.
WORK ORDER SUMMARY

Client Name:  ALPHA ANALYTICAL LABORATORIES  
Client Contact:  David S. Pingatore  
Contact's Email:  sspeaks@alpha-labs.com;david@alpha-labs.com; lquinn@alpha-labs.com  

Comments:

<table>
<thead>
<tr>
<th>Lab ID</th>
<th>Client ID</th>
<th>Matrix</th>
<th>Test Name</th>
<th>Containers /Composites</th>
<th>Bottle &amp; Preservative</th>
<th>De- chlorinated</th>
<th>Collection Date &amp; Time</th>
<th>TAT</th>
<th>Sediment Content</th>
<th>Hold</th>
<th>SubOut</th>
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</thead>
<tbody>
<tr>
<td>1701B45-001A</td>
<td>C1</td>
<td>Water</td>
<td>E200.7 (Silicon)</td>
<td>1</td>
<td>250mL HDPE w/ HNO3</td>
<td></td>
<td>1/22/2017 11:00</td>
<td>5 days</td>
<td>Present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1701B45-002A</td>
<td>C2</td>
<td>Water</td>
<td>E200.7 (Silicon)</td>
<td>1</td>
<td>250mL HDPE w/ HNO3</td>
<td></td>
<td>1/22/2017 11:00</td>
<td>5 days</td>
<td>Present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1701B45-003A</td>
<td>C3</td>
<td>Water</td>
<td>E200.7 (Silicon)</td>
<td>1</td>
<td>250mL HDPE w/ HNO3</td>
<td></td>
<td>1/22/2017 11:00</td>
<td>5 days</td>
<td>Present</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES:  - STLC and TCLP extractions require 2 days to complete; therefore, all TATs begin after the extraction is completed (i.e., One-day TAT yields results in 3 days from sample submission).
- MAI assumes that all material present in the provided sampling container is considered part of the sample - MAI does not exclude any material from the sample prior to sample preparation unless requested in writing by the client.
<table>
<thead>
<tr>
<th>Analysis</th>
<th>Due</th>
<th>Expires</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>17A2184-01 C1 [Water] Sampled 01/22/17 11:00</td>
<td></td>
<td></td>
<td>Ok-to-run nitrates out-of-hold ✔ ✔</td>
</tr>
<tr>
<td>Silicon Total ICP 6010</td>
<td>02/07/17 12:00</td>
<td>07/21/17 11:00</td>
<td></td>
</tr>
<tr>
<td>Containers Supplied:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250 mL Poly HNO3 (E)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 17A2184-02 C2 [Water] Sampled 01/22/17 11:00 | | | Ok-to-run nitrates out-of-hold ✔ ✔ |
| Silicon Total ICP 6010 | 02/07/17 12:00 | 07/21/17 11:00 |  |
| Containers Supplied: | | |  |
| 250 mL Poly HNO3 (E) | | |  |

| 17A2184-03 C3 [Water] Sampled 01/22/17 11:00 | | | Ok-to-run nitrates out-of-hold ✔ ✔ |
| Silicon Total ICP 6010 | 02/07/17 12:00 | 07/21/17 11:00 |  |
| Containers Supplied: | | |  |
| 250 mL Poly HNO3 (E) | | |  |

☐ Report to State

No container for 300.1 received.

Employed by: ___________________________

Sampler: ___________________________

System Name: ___________________________

User ID: ___________________________

System Number: ___________________________

W/QC J Flagg Excel

Mann 1/20/17 11:21

Page 1 of 1
Sample Receipt Checklist

Client Name: Alpha Analytical Laboratories
Project Name: 17A2184
WorkOrder #: 1701B45
Carrier: UPS

Date and Time Received: 1/26/2017 11:21
Date Logged: 1/26/2017
Received by: Maria Venegas
Logged by: Maria Venegas

Chain of Custody (COC) Information

- Chain of custody present? Yes ☑ No ☐
- Chain of custody signed when relinquished and received? Yes ☑ No ☐
- Chain of custody agrees with sample labels? Yes ☑ No ☐
- Sample IDs noted by Client on COC? Yes ☑ No ☐
- Date and Time of collection noted by Client on COC? Yes ☑ No ☐
- Sampler's name noted on COC? Yes ☑ No ☐

Sample Receipt Information

- Custody seals intact on shipping container/cooler? Yes ☑ No ☐ NA ☑
- Shipping container/cooler in good condition? Yes ☑ No ☐
- Samples in proper containers/bottles? Yes ☑ No ☐
- Sample containers intact? Yes ☑ No ☐
- Sufficient sample volume for indicated test? Yes ☑ No ☐

Sample Preservation and Hold Time (HT) Information

- All samples received within holding time? Yes ☑ No ☐ NA ☑
- Sample/Temp Blank temperature
  Temp: 1.3°C
- Water - VOA vials have zero headspace / no bubbles? Yes ☑ No ☐ NA ☑
- Sample labels checked for correct preservation? Yes ☑ No ☐
- pH acceptable upon receipt (Metal: <2; 522: <4; 218.7: >8)? Yes ☑ No ☐ NA ☑
- Samples Received on Ice?
  (Ice Type: WET ICE)
- UCMR3 Samples:
  Total Chlorine tested and acceptable upon receipt for EPA 522? Yes ☑ No ☐ NA ☑
  Free Chlorine tested and acceptable upon receipt for EPA 218.7, 300.1, 537, 539? Yes ☑ No ☐ NA ☑

Comments:
### Chain of Custody - Work Order

Reports and invoices delivered by email in PDF format

Lab No. 17A2184 
Pg. 1 of 3

Signature below authorizes work under terms stated on reverse side.

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>C1</td>
<td>1/23/17</td>
<td>1:00</td>
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<table>
<thead>
<tr>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
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<tbody>
<tr>
<td>8270 Semivolatiles</td>
<td>Total Nitrogen, Ammonia as N</td>
<td>Silica SM400</td>
</tr>
<tr>
<td>Clade Fluoride Orthophosphate</td>
<td>Hg, Hg7470, Metals Digest</td>
<td>Silica 60/10 sub MA</td>
</tr>
<tr>
<td>IC P 6010 Scan</td>
<td>Sample, MDL Reporting</td>
<td>Handling &amp; disposal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TAT</th>
<th>Temp upon Receipt °C</th>
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<tbody>
<tr>
<td>Standard 10 days</td>
<td>Ukiah temp: 2.4°</td>
</tr>
<tr>
<td>Rush: 5 days</td>
<td>Dublin temp:</td>
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<tr>
<td>48 hours</td>
<td>Elk Grove temp:</td>
</tr>
<tr>
<td>Other: 1 day</td>
<td></td>
</tr>
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</table>

Lab preapproval required.

Sample Notes or CDPH Source Numbers:

- 1L BRA (NP)
- 1L poly (H2SO4) - need 750
- 1L poly (NP) - need 750
- 250mL poly (HNO3)
- 250mL poly (HNO3)

Nitrates, Nitrites & Others
OK to run out of stock
per David (204 1/24/17)

<table>
<thead>
<tr>
<th>Relinquished by</th>
<th>Received by</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brad Finney</td>
<td>UPS Ground via AAL acct # 894250</td>
<td>1/24/17</td>
<td>09:36</td>
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CDPH Write On EDT Transmission? Yes No

State System Number:

If "Y" please enter the Source Number(s) in the column above

CA Geotracker EDF Report?

Global ID: Sampling Company Log Code:

EDF to (Email Address):

Travel and Site Time: Message: Misc. Supplies:
# Chain of Custody - Work Order

Reports and Invoices delivered by email in PDF format

Lab No: 17A2184  Pg 2 of 3

<table>
<thead>
<tr>
<th>Company: Humboldt State University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address: Environmental Resources &amp; Engineering, 1 Harpst Street, Arcata CA 95521</td>
</tr>
<tr>
<td>Phone/Fax: 707-826-3918</td>
</tr>
<tr>
<td>Email: <a href="mailto:brad.finney@humboldt.edu">brad.finney@humboldt.edu</a></td>
</tr>
</tbody>
</table>

Field Sampler - Printed Name & Signature: Brad Finney

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>1/23/17</td>
<td>11:06</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Container</th>
<th>Preservative</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>4ml Vial</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poly</td>
<td>Glass</td>
<td>Sleeve</td>
</tr>
<tr>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Total Number of Containers per Sample ID:

- 8270 Semivolatiles
- Total N, Ammonia as N
- Chloride Fluoride Orthophosphate
- Silica, ICP-6010 Scan, Hg, Ag, metals, digest
- Silicon 6010 sub MAI

Handing & Disposal:
- Bag Sample, MOL reporting
- Standard Excel EDD file

Sample Notes or CDPH Source Numbers:
- 1L BRA (NP)
- 1L poly (H2SO4) - need 750
- 1L poly (NP) - need 750
- 250mL poly (HNO3)
- 250mL poly (HNO3)

Note: No 3.1ortho
Ok to run out of holk per David 1/24/17

Relinquished by Brad Finney

UPS Ground via AAL acct # 894250

Received by

CDPH Write On EDT Transmission? Yes

State System Number:

If "Y" please enter the Source Number(s) in the column above

CA Geotracker EDF Report? Yes

Global ID: Sampling Company Log Code

EDF to (Email Address)

Travel and Site Time: Mileage: Misc. Supplies:
A Chain of Custody - Work Order report is shown in the image. It contains detailed information about the analytical tasks, request for analysis, TAT (Turnaround Time) specifications, and the sample processing details. The form includes various sections such as the company's details, project information, analysis request, TAT and temperature notes, and sample identification details.

The sample identification section lists different samples with their respective dates and times, indicating when and how they were collected. Additionally, there are notes about the sample's preservative, matrix, and other handling instructions. The form also includes a section for relinquished samples and the details of the receiver.

The report also mentions the use of EDT (Environmental Data Tracking System) for transmission and has a section for writing CDPH (California Department of Public Health) EDF (Environmental Data Form) reports. It's a comprehensive document used for tracking and transactions in laboratory settings.
Appendix D – Preliminary List of Constituents
17 June 2016

To: CARE Project Team

Copy to: Dr. Brad Finney (HSU)

From: Jonathan Eller & Ryan Crawford

Tel: 415-296-3609

Subject: PET Carpet Feasibility Study: Preliminary List of Constituents

Job no: 11121650

Purpose and Use of this Document

The purpose of this document is to assist in laboratory testing to support studying the feasibility of using recycled PET carpet by identifying potential constituents of concern.

Included is a preliminary list of constituents that may be of concern if recycled PET carpet is subjected to prolonged exposure to sunlight, water, pH extremes, organics/non-point source heavy end oils, or mechanical abrasion. This list may be modified based on further investigation, and should be considered a working document.

Constituents were selected for inclusion if they met these requirements:

1. The constituent may be present due to either chemical degradation of the PET polymer chain, or by having been embedded in the polymer matrix as a result of known manufacturing or recycling processes;

2. There is a likelihood of the constituent either dissolving/suspending in water or off-gassing under the specified conditions, as revealed by an initial survey of available literature; and

3. A regulatory standard exists for the constituent.

The constituents chosen include metals, phthalate esters and carbon monoxide, as shown in Table 1. Metal catalysts are used in commercial PET synthesis, and can be present in the polymer matrix (Ref 1-3). Phthalate esters, such as Di (2-ethylhexyl)phthalate (DEHP) and Di-n-butyl phthalate (DNBP) may be used in the copolymerization of PET, added as a plasticizer, or introduced as an impurity during the manufacturing process (Refs 4-5). Carbon monoxide is produced by photodegradation of PET (Refs 6-8).

In addition to these constituents, the table also lists the parameters Turbidity, Color, Odor and Volatile organic carbons (VOCs); these parameters may be introduced due to the release of multiple species, including those not specifically addressed here. A full VOC analysis using EPA Method 8260B is recommended to cover release of airborne or volatile contaminants not found in the literature.

A variety of other compounds were considered but not included at this stage, due to either a lack of regulation or a poor understanding of the likeliness of their presence or release. These may be the subject of subsequent investigations. Such compounds may originate from:

- Non-regulated breakdown products of PET and the PET blend (including ethylene glycol,
terephthalic acid, acetaldehyde and formaldehyde)

- Additives in the carpet manufacturing process (e.g., dyes/pigments, miticides, flame retardants, anti-static coatings, stain protection, UV stabilizers)
- Additives during the carpet’s lifespan (e.g., cleaners, pest treatment)
- Metal catalysts used in chemical recycling of PET

Table 1: Preliminary List of Constituents

<table>
<thead>
<tr>
<th>Constituent or Parameter</th>
<th>Regulatory Limit(1)</th>
<th>Conditions of Release</th>
<th>Medium of Release(2)</th>
<th>Source</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony (Sb)</td>
<td>USEPA MCL 6 μg/L</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td>Catalyst for PET synthesis</td>
<td>1-3</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>SFB RWQCB Tier 1 ESL 3 μg/L</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td>Catalyst for PET synthesis</td>
<td>3</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>CalEPA: SMCL 50 μg/L</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td>Catalyst for PET synthesis</td>
<td>3</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>CalEPA: SMCL 300 μg/L</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td>Catalyst for PET synthesis</td>
<td>3</td>
</tr>
<tr>
<td>Di (2-ethylhexylphthalate) (DEHP)</td>
<td>CalEPA MCL 4 μg/L</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td>Possible reagents, plasticizers for PET, or impurities introduced in manufacture</td>
<td>4, 5</td>
</tr>
<tr>
<td>Di-n-butyl phthalate (DNBP)</td>
<td>CalEPA MCL 7 μg/L</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Constituent or Parameter</td>
<td>Regulatory Limit(^{(1)})</td>
<td>Conditions of Release</td>
<td>Medium of Release(^{(2)})</td>
<td>Source</td>
<td>Reference</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>-----------------------</td>
<td>-----------------------------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>Carbon monoxide (CO)(^{(3)})</td>
<td>CalEPA ARB 20 ppm human air exposure for one hour</td>
<td>UV light, time</td>
<td>Air</td>
<td>Photodegradate of PET</td>
<td>6-8</td>
</tr>
<tr>
<td>Turbidity</td>
<td>CalEPA MCL 5 NTU</td>
<td>UV light, temp, time, exposure to organics, high or low pH, abrasion</td>
<td>Water</td>
<td>Insoluble species or particles from degraded plastic</td>
<td>8</td>
</tr>
<tr>
<td>Color, Apparent</td>
<td>CalEPA SMCL 15 UNITS</td>
<td>Temp, time, exposure to organics, high or low pH</td>
<td>Water</td>
<td>Carpet dyes or pigments, various colored leachates</td>
<td>8</td>
</tr>
<tr>
<td>Odor threshold</td>
<td>CalEPA MCL 3 TON</td>
<td>UV light, abrasion, high or low pH</td>
<td>Water, Air</td>
<td>Formaldehyde, acetaldehyde, esters &amp; other off-gassed or volatile degradates</td>
<td>4-8</td>
</tr>
<tr>
<td>Volatile organic carbons (VOCs)(^{(4)})</td>
<td>Various from above</td>
<td>Water, Air</td>
<td></td>
<td></td>
<td>4-8</td>
</tr>
</tbody>
</table>

Notes:

1. For groundwater or surface water. SFBRWQCB = San Francisco Bay Regional Water Quality Control Board; ESL = Environmental Screening Limit; (S)MCL = (Secondary) Maximum Contamination Limit; μg/L = microgram per liter
2. Where the constituent is likely to be found if released
3. Anticipated only at very low levels, and may not be feasible for testing under these conditions
4. Recommend a standard EPA Method 8260B VOC full list analysis with chromatograms to cover potential release of regulated VOCs not mentioned in the literature.
References


www.ghd.com
Appendix B – Pilot Study 1: Wastewater Filtration using Shredded Recycled PET Carpet Media (Phase II)
Wastewater Filtration using Shredded Recycled PET Carpet Media

Prepared by
Brad Finney, Eileen Cashman, and Kelsey Burrell
Humboldt State University
Environmental Resources Engineering
1 Harpst Street
Arcata, CA 95521

HUMBOLDT STATE UNIVERSITY

January 2018
# List Of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Avg</td>
<td>Average</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>CA</td>
<td>California</td>
</tr>
<tr>
<td>CalRecycle</td>
<td>California Department of Resources Recycling and Recovery</td>
</tr>
<tr>
<td>CARE</td>
<td>Carpet America Recovery Effort</td>
</tr>
<tr>
<td>CCSP</td>
<td>California Carpet Stewardship Program</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>D&lt;sub&gt;10&lt;/sub&gt;</td>
<td>Diameter at which 10% of the sample is smaller than this size</td>
</tr>
<tr>
<td>ft</td>
<td>foot or feet</td>
</tr>
<tr>
<td>gm</td>
<td>gram</td>
</tr>
<tr>
<td>GPM</td>
<td>gallons per minute</td>
</tr>
<tr>
<td>hr</td>
<td>hour</td>
</tr>
<tr>
<td>HSU</td>
<td>Humboldt State University</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram</td>
</tr>
<tr>
<td>L</td>
<td>liter</td>
</tr>
<tr>
<td>MDL</td>
<td>method detection limit</td>
</tr>
<tr>
<td>mil</td>
<td>thousandth of an inch</td>
</tr>
<tr>
<td>mg</td>
<td>milligram</td>
</tr>
<tr>
<td>μg</td>
<td>microgram</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>NTU</td>
<td>Nephelometric Turbidity Units</td>
</tr>
<tr>
<td>PCC</td>
<td>Post-Consumer Carpet</td>
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<tr>
<td>PET</td>
<td>Polyethylene Terephthalate</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>RPC</td>
<td>Recycled PET Carpet</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Spec Cond</td>
<td>Specific Conductivity</td>
</tr>
<tr>
<td>TCLP</td>
<td>Toxic Characteristic Leaching Procedure</td>
</tr>
<tr>
<td>TDA</td>
<td>Tire Derived Aggregate</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VOC</td>
<td>Volatile Organic Compound</td>
</tr>
<tr>
<td>WET</td>
<td>Waste Extraction Test</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater Treatment Plant</td>
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</table>
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<th>Description</th>
<th>Page</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Location of the experimental site adjacent to the primary oxidation pond at the City of Arcata WWTP.</td>
<td>7</td>
</tr>
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<td>2</td>
<td>Outer containment structure for shredded RPC media wastewater filter leveled on concrete pier blocks.</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Reinforced polyethylene lined filter with perforated water delivery pipe and filled with shredded RPC media.</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Shredded RPC media filter influent and effluent concentration of aluminum.</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Shredded RPC media filter influent and effluent concentration of antimony.</td>
<td>13</td>
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<td>Shredded RPC media filter influent and effluent concentration of arsenic.</td>
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</tr>
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<td>7</td>
<td>Shredded RPC media filter influent and effluent concentration of mercury.</td>
<td>14</td>
</tr>
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<td>8</td>
<td>Shredded RPC media filter influent and effluent concentration of nickel.</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>Shredded RPC media filter influent and effluent concentration of selenium.</td>
<td>15</td>
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<td>10</td>
<td>Shredded RPC media filter influent and effluent concentration of barium.</td>
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<td>11</td>
<td>Shredded RPC media filter influent and effluent concentration of copper.</td>
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<tr>
<td>12</td>
<td>Shredded RPC media filter influent and effluent concentration of iron.</td>
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<td>13</td>
<td>Shredded RPC media filter influent and effluent concentration of magnesium.</td>
<td>18</td>
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<tr>
<td>14</td>
<td>Shredded RPC media filter influent and effluent concentration of manganese.</td>
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<td>15</td>
<td>Shredded RPC media filter influent and effluent concentration of sodium.</td>
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<td>16</td>
<td>Shredded RPC media filter influent and effluent concentration of zinc.</td>
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<td>Shredded RPC media filter influent and effluent concentration of BOD.</td>
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<td>Shredded RPC media filter influent and effluent concentration of COD.</td>
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<td>Shredded RPC media filter influent and effluent concentration of TSS.</td>
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<td>20</td>
<td>Shredded RPC media filter influent and effluent concentration of turbidity.</td>
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<td>Shredded RPC media filter influent and effluent concentration of oil &amp; grease.</td>
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<td>Shredded RPC media filter influent and effluent specific conductivity.</td>
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<td>Shredded RPC media filter influent and effluent concentration of ammonia.</td>
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<td>Shredded RPC media filter influent and effluent concentration of chloride.</td>
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<td>26</td>
<td>Shredded RPC media filter influent and effluent concentration of sulfate.</td>
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<td>27</td>
<td>Shredded RPC media filter influent and effluent concentration of orthophosphate.</td>
<td>28</td>
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<tr>
<td>28</td>
<td>Shredded RPC media filter influent and effluent concentration of acetone.</td>
<td>29</td>
</tr>
</tbody>
</table>
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1 Introduction

California Assembly Bill 2398, enacted in 2010, established the California Carpet Stewardship Program (CCSP). The goal of the CCSP is to provide funding to establish, increase, and improve the collection, recycling, and utilization of California-generated post-consumer carpet (PCC) in recycled-content product manufacturing. The bill designated Carpet America Recovery Effort (CARE), with oversight from the California Department of Resources Recycling and Recovery (CalRecycle), to administer the CCSP.

CARE has successfully created programs to support the collection and reuse of nylon and polyethylene terephthalate (PET) carpet waste. Recycled PET carpet (RPC) material outlets and diversion streams are not yet at the scale necessary to reuse all the current RPC streams. CARE is promoting research to identify potential uses of RPC materials in civil engineering applications.

As part of a coordinated effort to identify potential reuse streams for RPC material, Humboldt State University (HSU) performed laboratory analyses to determine the density, compressibility, hydraulic conductivity, and porosity values for three forms of RPC) products: shredded carpet, face fiber (or “fluff”), and carpet underlayment (carpet “pad”) (Finney et al., 2016). During the laboratory analysis the concentration of numerous constituents was determined for water saturating RPC for various durations. Leachate water quality results show that RPC material is relatively benign. Additionally, shredded RPC was analyzed by the Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) protocols, and results indicate that RPC is not considered a hazardous material.

Material property testing conducted by HSU concluded that RPC products are characterized as lightweight materials with high porosity but lower hydraulic conductivity when compared to conventional construction materials like soil and gravel. The RPC products examined generally also have high compressibility and high surface area (Finney et al., 2016). When used as a water filter, the high surface area of the materials provides for physical filtering and removal of some water quality constituents and an opportunity for a large attached growth bacteria community to transform some water quality constituents to less harmful forms. Based on a review of the existing literature and these laboratory results, further research was proposed that included three pilot studies for applications of RPC in stormwater and wastewater treatment.

This report addresses one of three pilot studies initiated; the use of shredded RPC as a substitute for rock aggregate fill in septic tank leach fields, an application in wastewater treatment. The experiment was designed to allow direct comparison to the results of a similar experiment that examined using tire derived aggregate (TDA) as a substitute for conventional rock aggregate media in leach fields. Finney et al. (2013) found that TDA performed as well or better than rock aggregate in treating septic tank effluent with the improved performance theorized to be related to the higher surface area of the TDA media compared to the rock aggregate. Shredded RPC has the advantage of a much higher specific surface area than either rock or TDA, so the treatment performance with this media may be even greater than either of the other two materials.
2 EXPERIMENTAL SET-UP AND SAMPLING METHODOLOGY

An above ground filtration system was designed and constructed to evaluate the effectiveness of using recycled PET carpet material (shredded RPC) as filtration media in septic system leach line drainage for primary treated wastewater. The filter was designed and operated to match an earlier investigation by Finney et al. (2013), where use of TDA was compared to conventional rock aggregate as a media in a septic tank leach field setting. The experimental shredded RPC media filter was located at the City of Arcata wastewater treatment facility adjacent to oxidation pond 1 (Figure 1), the same location used in the previous TDA experiment. This oxidation pond receives primary treated (screening and settling) municipal wastewater from the headworks of the Arcata treatment facility. The water quality is typical of primary treated municipal wastewater except that it has higher suspended solids due to the algal cells growing within in the pond.

The filter was a 40-foot long plywood box, with a 2-ft by 2-ft cross section (Figure 2). The box was installed level on concrete foundation piers and lined with a 30 mil reinforced polyethylene fabric. Approximately 1,400 pounds of shredded RPC was used as the filtration media (Figure 3). The shredded RPC was purchased from Circular Polymers Incorporated, Lincoln, CA. The generally rectangular carpet pieces had lengths and widths ranging from 1 to 4 inches. Oxidation pond water was pumped to a 4-inch perforated PVC pipe that was suspended level along the top of media, delivering the wastewater influent evenly along nearly the full length of the filter. The wastewater trickled vertically through the shredded carpet media, then flowed horizontally to a drain at one end of the filter, and finally flowed by gravity back to the oxidation pond.

Figure 1 Location of the experimental site adjacent to the primary oxidation pond at the City of Arcata WWTP.
Figure 2 Outer containment structure for shredded RPC media wastewater filter leveled on concrete pier blocks.
The shredded RPC filter system was run intermittently on a schedule designed to simulate the hydraulic loading of a typical household septic system. A submersible pump in the oxidation pond delivered wastewater to the filter header pipe three times a day for 90 minutes at an approximate rate of 3 GPM. The total hydraulic loading to the system was approximately 810 gallons per day. Had the filter been in continuous operation, the hydraulic surface loading rate would be equivalent to a rate of 2.2 m³/m²/day (2.2 m³ wastewater applied per m² of the horizontal surface area of the filter per day).

The shredded RPC wastewater filter was in operation from June 27, 2018 until October 15, 2018. The water temperature and water level inside the filter was continuously measured and an influent and effluent water sample was collected at two to three week intervals during the period of filter operation resulting in seven sample pairs. State certified analytical labs determined the value of 97 different water quality constituents and characteristics for each sample. The constituents examined included 18 metals, 68 volatile organics, and a variety of conventional wastewater characteristics and constituents. Table 1 provides a list of constituents that were detected in at least one sample and a complete list of all constituents examined is provided in Appendix A.
Table 1 Constituents detected in the filter influent or effluent in at least one sample event.

<table>
<thead>
<tr>
<th>Category</th>
<th>Constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>aluminum, antimony, arsenic, barium, copper, iron, magnesium, manganese, mercury, nickel, selenium, sodium, zinc</td>
</tr>
<tr>
<td>Anions</td>
<td>chloride, nitrate, orthophosphate, sulfate</td>
</tr>
<tr>
<td>Volatile Organics</td>
<td>acetone</td>
</tr>
<tr>
<td>Cations</td>
<td>ammonia</td>
</tr>
<tr>
<td>Other Conventional Wastewater parameters</td>
<td>BOD, COD, oil &amp; grease, specific conductance, turbidity, TSS</td>
</tr>
</tbody>
</table>
3 SUMMARY OF WATER QUALITY RESULTS

Results from the analysis of the influent and effluent samples from the seven sampling events for the shredded RPC filter are presented and discussed in the subsections below. For statistical and graphical purposes, all sampled values determined to be below the method detection level (MDL) are treated as a zero value. In any case where a sample was not taken for a constituent, it is noted in the figures. When removal rates of a constituent are presented, a negative removal rate indicates that the effluent concentration was higher than the influent concentration. The results are grouped into categories of 1) metals, 2) conventional wastewater parameters, 3) nitrogen, and 4) other constituents which are anions and VOCs.

Metals

Thirteen of the eighteen different metals examined resulted in at least one instance of a detectable concentration in the wastewater samples. Six of these metals (aluminum, antimony, arsenic, mercury, nickel and selenium) were infrequently observed above the MDL (Table 2) and most of those values were just above the detection level (Figure 4 - Figure 9). Aluminum, antimony, mercury and nickel were detected sporadically in the wastewater samples and in most cases the effluent concentration was less than the influent concentration.

Arsenic and selenium were only found in effluent samples. Arsenic was detected in one effluent sample on 8/21/18 at a concentration of 0.008 mg/l (Figure 6). This concentration is below the regulatory limit for drinking water of 0.01 mg/l. Detectable selenium concentrations were observed twice (8/8/18 and 8/21/18) in the effluent at 0.01 mg/l and 0.044 mg/l respectively (Figure 9). Both of these concentrations are less than the regulatory limit for drinking water of 0.05 mg/l. While these selenium concentrations are not of concern, they were somewhat surprising as previous research and a leaching study performed in this experiment did not identified this metal as associated with leachate from PET carpet. The presence of selenium in the effluent samples may reflect minor differences in carpet composition from what was tested during the leachate trials or it may be from debris introduced into the carpet while in use as a floor covering.

Due to the small sample size and because so many of the measured values are very close to the detection level, calculating reliable estimates of removal rates of the infrequently observed metals in the filter is not possible. However the data does indicate that the shredded RPC media filter generally had a net positive removal of aluminum, antimony, mercury and nickel. The data also suggests that use of shredded RPC as a wastewater filtration media will not result in significant leaching of arsenic and selenium.
Table 2 Summary analysis of metals infrequently observed above detection levels.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Numbers of samples with detectable concentration</th>
<th># of samples where Influent &gt; Effluent</th>
<th>Average Detected Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (mg/l)</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.219</td>
</tr>
<tr>
<td>Antimony (mg/l)</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.008</td>
</tr>
<tr>
<td>Arsenic (mg/l)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.008</td>
</tr>
<tr>
<td>Mercury (μg/l)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.025</td>
</tr>
<tr>
<td>Nickel (mg/l)</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.016</td>
</tr>
<tr>
<td>Selenium (mg/l)</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.054</td>
</tr>
</tbody>
</table>

Figure 4 Shredded RPC media filter influent and effluent concentration of aluminum.
Figure 5 Shredded RPC media filter influent and effluent concentration of antimony.

Figure 6 Shredded RPC media filter influent and effluent concentration of arsenic.
Figure 7. Shredded RPC media filter influent and effluent concentration of mercury.

Figure 8. Shredded RPC media filter influent and effluent concentration of nickel.
Seven of the metals examined were present in all influent water samples and most of the effluent water samples (Table 3, Figure 10 - Figure 16). Concentrations for barium, copper, iron, manganese, and zinc were always greater in the influent water sample than the effluent water sample. The filter is particularly effective in removing copper, iron, manganese, and zinc, with average removal rates ranging from 61% to 74%. The average removal rate for barium is considerably lower at 29% percent. Removal rates for iron, manganese, and zinc are more than three times greater than reported by Finney et al. (2013) for a comparable system using rock aggregate as a media.

Concentrations of magnesium and sodium in the effluent water samples were usually the same or slightly higher than influent concentrations (Figure 13 and Figure 15). A leaching experiment conducted with a sample of shredded RPC used in the filter and previous research by Finney et al. (2016) using material from a different source showed that all seven metals are leached from shredded RPC media. After allowing shredded carpet used in the filter to soak in distilled water for two weeks, the leaching rate for these seven metals was determined to range from 0.778 to 1,400 mg/kg of carpet (Table 4). In a similar experiment with a two month soak of shredded RPC media, Finney et al. (2016) found that the leaching rate for these constituents ranged from 0.093 to 2,467 mg/kg carpet (Table 4). The differences in the leaching rate for a constituent from one study to the next are likely due to differences in carpet composition and random variability in sampling. Further study would be required to determine whether the apparent lack of a net removal of magnesium and sodium in the filter is random statistical variability or might be because those two metals had the highest rate of leaching from the shredded RPC filter media.

Figure 9 Shredded RPC media filter influent and effluent concentration of selenium.
Table 3 Summary analysis of metals consistently detected in wastewater samples.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Numbers of samples with detectable concentration</th>
<th># of samples where Influent &gt; Effluent</th>
<th>Average (SD) Concentration (mg/l)</th>
<th>Average Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent</td>
<td>Effluent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>7</td>
<td>7</td>
<td>0.11 (0.01)</td>
<td>0.08 (0.01)</td>
</tr>
<tr>
<td>Copper</td>
<td>7</td>
<td>5</td>
<td>0.05 (0.04)</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Iron</td>
<td>7</td>
<td>6</td>
<td>0.35 (0.20)</td>
<td>0.12 (0.06)</td>
</tr>
<tr>
<td>Magnesium</td>
<td>7</td>
<td>7</td>
<td>11.4 (0.79)</td>
<td>11.9 (1.07)</td>
</tr>
<tr>
<td>Manganese</td>
<td>7</td>
<td>7</td>
<td>0.14 (0.02)</td>
<td>0.04 (0.01)</td>
</tr>
<tr>
<td>Sodium</td>
<td>7</td>
<td>7</td>
<td>57.1 (2.41)</td>
<td>59.0 (4.93)</td>
</tr>
<tr>
<td>Zinc</td>
<td>7</td>
<td>3</td>
<td>0.05 (0.06)</td>
<td>0.01 (0.01)</td>
</tr>
</tbody>
</table>

Figure 10 Shredded RPC media filter influent and effluent concentration of barium.
Figure 11 Shredded RPC media filter influent and effluent concentration of copper.

Figure 12 Shredded RPC media filter influent and effluent concentration of iron.
Figure 13 Shredded RPC media filter influent and effluent concentration of magnesium.

Figure 14 Shredded RPC media filter influent and effluent concentration of manganese.
Figure 15 Shredded RPC media filter influent and effluent concentration of sodium.

Figure 16 Shredded RPC media filter influent and effluent concentration of zinc.
Table 4 Leaching rate for metals from shredded PET carpet following a two-week and two-month soaking period.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Leaching rate from 2-week soak (mg/kg carpet)</th>
<th>Leaching rate from 2-month soak* (mg/kg carpet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium</td>
<td>0.778</td>
<td>0.093</td>
</tr>
<tr>
<td>Copper</td>
<td>0.933</td>
<td>0.530</td>
</tr>
<tr>
<td>Iron</td>
<td>10.9</td>
<td>5.00</td>
</tr>
<tr>
<td>Magnesium</td>
<td>76.3</td>
<td>38.7</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.791</td>
<td>0.451</td>
</tr>
<tr>
<td>Sodium</td>
<td>1400</td>
<td>2467</td>
</tr>
<tr>
<td>Zinc</td>
<td>3.11</td>
<td>4.20</td>
</tr>
</tbody>
</table>

*from Finney et al. (2016)

Conventional Wastewater Parameters

Water quality parameters that are traditionally associated with wastewater analysis, including BOD, COD, TSS, turbidity, oil & grease, and specific conductance, were analyzed for each sample event (Table 5, Figure 17 - Figure 22). Influent concentrations of BOD, COD, TSS and turbidity were consistently reduced by the shredded RPC media filter system. Average percent reductions ranged from 36% for COD to 57% for TSS.

On average, the shredded RPC media filtration system resulted in a 20% reduction in oil and grease over influent concentrations. However, the sample events were varied and several spikes of oil and grease were seen in effluent water samples over the sampling period.

Specific conductance values were relatively unaffected by the shredded RPC media filtration system with effluent values slightly higher than influent values. However, with the exception of one possibly erroneous effluent value, all measurements were within the range of instrument error and cannot be interpreted as different from each other.
Table 5 Summary of analysis for conventional wastewater parameters in wastewater samples.

<table>
<thead>
<tr>
<th>Water Quality Constituent</th>
<th>Number of samples</th>
<th>% of samples where Influent &gt; Effluent</th>
<th>Average (SD) Influent Concentration</th>
<th>Average (SD) Effluent Concentration</th>
<th>Avg Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (mg/l)</td>
<td>7</td>
<td>7</td>
<td>140 (37)</td>
<td>81 (34)</td>
<td>42</td>
</tr>
<tr>
<td>COD (mg/l)</td>
<td>7</td>
<td>7</td>
<td>217 (57)</td>
<td>139 (35)</td>
<td>36</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>7</td>
<td>7</td>
<td>102 (15)</td>
<td>44 (17)</td>
<td>57</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>6</td>
<td>6</td>
<td>51.7 (16.5)</td>
<td>28.6 (11.3)</td>
<td>46</td>
</tr>
<tr>
<td>Oil &amp; grease (mg/l)</td>
<td>7</td>
<td>5</td>
<td>3.53 (4.34)</td>
<td>3.20 (3.99)</td>
<td>20</td>
</tr>
<tr>
<td>Spec Cond (μm/cm)</td>
<td>6</td>
<td>1</td>
<td>655 (49)</td>
<td>672 (23)</td>
<td>-3</td>
</tr>
</tbody>
</table>

Figure 17 Shredded RPC media filter influent and effluent concentration of BOD.
Figure 18 Shredded RPC media filter influent and effluent concentration of COD.

Figure 19 Shredded RPC media filter influent and effluent concentration of TSS.
Figure 20 Shredded RPC media filter influent and effluent concentration of turbidity.

Figure 21 Shredded RPC media filter influent and effluent concentration of oil & grease.
Nitrogen

Concentrations of ammonia-N ranged from approximately 5 to 21 mg/l in the shredded RPC media filter influent to approximately 3 to 16 mg/l in the effluent, with an average reduction of 2.8 mg/l (Table 6, Figure 23). In contrast, nitrate-N was essentially zero in the influent (0.3 mg/l on average over seven samples) and averaged 5.1 mg/l in the effluent (Table 6, Figure 24). Given the generally aerobic environment in the shredded RPC media filter, the primary mechanism for the reduction of ammonia would normally be by nitrification and the rate of denitrification would be insignificant. Under these conditions, every mg/l reduction in the ammonia concentration would result in the same mg/l increase in the nitrate concentration. However in this experiment, the data indicates that the rate of increase in nitrate exceeds the rate of decrease in ammonia.

This situation could result from an internal source of ammonia from the conversion of organic nitrogen to ammonia within the filter. The larger increase in the nitrate concentration compared to the decrease in the ammonia concentration may also result from reactions occurring in the shredded RPC media between operational periods. The behavior was most apparent in samples taken during the morning operational period where some water had been sitting in the filter for 12 hours since the previous evening operational period. Shifting the sample time to coincide with the end of the midday operational period (4 hours after the morning period) resulted in ammonia concentration reductions that were nearly identical to the increase in nitrate concentrations through the filter. This result indicates that the RPC media filter provided a suitable environment for ammonia reduction by nitrification and that no significant denitrification was occurring in the filter. None of the other water quality parameters investigated during this experiment exhibited this shift in behavior based on the time of the sample, eliminating a concern that the timing of the samples might change the conclusions of the experiment.
Table 6 Summary of analysis for ammonia and nitrate in wastewater samples.

<table>
<thead>
<tr>
<th>Water Quality Constituent</th>
<th>Number of samples</th>
<th>% of samples where Influent &gt; Effluent</th>
<th>Average (SD) Influent Concentration</th>
<th>Average (SD) Effluent Concentration</th>
<th>Avg Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia-N (mg/l)</td>
<td>7</td>
<td>7</td>
<td>10.3 (5.1)</td>
<td>7.5 (4.3)</td>
<td>28</td>
</tr>
<tr>
<td>Nitrate-N (mg/l)</td>
<td>7</td>
<td>0</td>
<td>0.31 (0.29)</td>
<td>5.10 (1.16)</td>
<td>-36</td>
</tr>
</tbody>
</table>

Figure 23 Shredded RPC media filter influent and effluent concentration of ammonia.
Figure 24 Shredded RPC media filter influent and effluent concentration of nitrate.

Other Constituents

The remaining constituents that were detected in the wastewater samples include the anions chloride, sulfate, orthophosphate, and one volatile organic, acetone. The concentrations of the anions chloride and sulfate were unaffected by the shredded RPC media filter with concentrations in the influent essentially equal to concentrations in the effluent of the filter (Table 7, Figure 25 and Figure 26). The average orthophosphate concentration increased from 14.0 mg/l in the influent to 16.2 mg/l in the effluent with a trend toward increasing effluent values towards the end of the sampling period (Figure 27). Leaching studies with shredded carpet samples had identified the material as a potential source for phosphates, so the slight increase in concentration passing through the filter is not surprising.

Acetone was the only volatile organic detected out of 67 compounds investigated in the filter water samples. Acetone was detected in the influent and effluent during three sample events, with concentrations ranging from 7.3 to 27 µg/l. The influent concentrations were either relatively unaffected or slightly reduce by the shredded RPC media filtration system (Figure 28).
Table 7 Summary of analysis for anions.

<table>
<thead>
<tr>
<th>Water Quality Constituent</th>
<th>Number of samples</th>
<th>% of samples where Influent &gt; Effluent</th>
<th>Average (SD) Influent Concentration</th>
<th>Average (SD) Effluent Concentration</th>
<th>Avg Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride (mg/l)</td>
<td>5</td>
<td>2</td>
<td>81.8 (4.8)</td>
<td>83.2 (3.7)</td>
<td>-2</td>
</tr>
<tr>
<td>Sulfate (mg/l)</td>
<td>6</td>
<td>1</td>
<td>23.5 (1.4)</td>
<td>24.7 (1.5)</td>
<td>-5</td>
</tr>
<tr>
<td>Orthophosphate (mg/l)</td>
<td>6</td>
<td>0</td>
<td>14.0 (1.79)</td>
<td>16.2 (2.32)</td>
<td>-17</td>
</tr>
</tbody>
</table>

Figure 25 Shredded RPC media filter influent and effluent concentration of chloride.
Figure 26 Shredded RPC media filter influent and effluent concentration of sulfate.

Figure 27 Shredded RPC media filter influent and effluent concentration of orthophosphate.
Figure 28 Shredded RPC media filter influent and effluent concentration of acetone.

**Comparison to other filtration systems**

Comparing the performance of the shredded RPC media filter to other filtration technologies is difficult because primary oxidation pond water is rarely filtered in practice. There are a number of systems in use for filtering septic tank effluent, but that waste lacks the abundant algal cells that characterize oxidation pond water. The rock aggregate and TDA media leach fields investigated by Finney et al. (2013) were the same dimensions as the shredded RPC media filter, were constructed with the same water distribution system, were operated with the same loading schedule and flow rates, and the influent was from the same oxidation pond as used in this experiment. The influent and effluent of the leach fields were regularly sampled over a 15 month operating period for some of the same water quality constituents measured in the present study (Table 8). The shredded RPC media filter had a much higher removal rate for all of the constituents the two experiments had in common (Table 9). In general, the shredded RPC media filter removal rate for these constituents was at least three times greater than the best removal rate for the rock or TDA media filter. The only disadvantage of the shredded RPC media compared to the rock and TDA is the lower hydraulic conductivity of the carpet. As summarized by GHD (2017), while the shredded RPC media has a relatively high porosity (0.45 to 0.6), the pore size is small and the hydraulic conductivity is one to two orders of magnitude lower than rock aggregate or TDA. While the hydraulic loading rate for both experiments was the same (approximately 3 GPM), that was near the maximum that could be sustained by the shredded RPC media without the water depth exceeding the filter depth of 2 feet. While the high surface area of the carpet fibers provides an ideal environment for attached bacteria that help reduce organic compounds in the wastewater and provide for efficient removal of suspended solids and the associated particulate metals, the shredded RPC media is much more likely to have a shorter operational life due to plugging compared to the rock or TDA.
Table 8 Average influent and effluent concentration of selected water quality constituents reported by Finney et al. (2013) in rock aggregate and TDA media leach fields.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Average Influent (mg/l)</th>
<th>Average Rock Effluent (mg/l)</th>
<th>Average TDA Effluent (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>0.80</td>
<td>0.68</td>
<td>4.3</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.14</td>
<td>0.13</td>
<td>0.16</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.03</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>BOD</td>
<td>88</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td>COD</td>
<td>183</td>
<td>176</td>
<td>161</td>
</tr>
<tr>
<td>TSS</td>
<td>102</td>
<td>85</td>
<td>88</td>
</tr>
<tr>
<td>Ammonia</td>
<td>11</td>
<td>9.8</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 9 Comparison of average removal rates for selected water quality constituents for rock, TDA and shredded RPC media filters.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Average Removal Rate (%)</th>
<th>Rock Aggregate*</th>
<th>TDA*</th>
<th>Shredded Carpet Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>8</td>
<td>-500</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>8</td>
<td>-20</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>20</td>
<td>-103</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td>1</td>
<td>10</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>1</td>
<td>11</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td>14</td>
<td>8</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>19</td>
<td>12</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

*from Finney et al. (2013)

The shredded RPC media filter can also be compared to an intermittent slow sand filter, a commonly used technology for upgrading the treatment efficiency of oxidation pond systems. While there is abundant literature on the performance of these sand filters, most of the performance data is based on filtering waste at a lower mass or hydraulic loading rate than used in this experiment. However, Traux and Shindala (1994) performed an experiment with a variety of configurations of slow sand filters using the effluent from the first cell of an oxidation pond system. The configurations they investigated involved four different effective media sizes and several different hydraulic loading rates. The highest surface hydraulic loading rate they used was 1.1 m$^3$/m$^2$/day, exactly half the rate of 2.2 m$^3$/m$^2$/day used in the shredded RPC media filter assuming continuous operation. At the 1.1 m$^3$/m$^2$/day loading rate, Traux and Shindala found that the run time before plugging on the intermittent sand filters was less than 10 days for all sand media grain sizes they investigated except the largest, which had a D$_{10}$ of 0.70mm and an operational time of 106 days before initial clogging was observed. The results from Traux and Shindala (1994) suggest that the shredded RPC media filter performance in removing common wastewater constituents is comparable or better than what would be expected of a slow sand
filter. The removal rate of BOD, COD, and TSS in the shredded RPC media filter was comparable to that in the intermittent sand filter that was loaded at half the rate (Table 10). The removal rate for the slow sand filter was significantly higher than that shredded RPC media filter for ammonia, which is not surprising given the lower loading rate.

Table 10 Comparison of average removal rates for selected water quality constituents for slow sand and shredded RPC media filter.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Average Removal Rate (%)</th>
<th>Slow Sand Filter*</th>
<th>Shredded RPC Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td></td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>COD</td>
<td></td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>TSS</td>
<td></td>
<td>68</td>
<td>57</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td></td>
<td>53</td>
<td>28</td>
</tr>
</tbody>
</table>

*from Truax and Shindala (1994), media 1, 1.1 m³/m²/day loading rate
4 SUMMARY AND CONCLUSION

An above ground filtration system was designed and constructed to evaluate the effectiveness of using recycled shredded RPC as filtration media in septic system leach line drainage for primary treated wastewater. The filter was designed and operated to match an earlier investigation where use of TDA was compared to conventional rock aggregate as a media in a septic tank leach field setting. The experimental shredded RPC media filter was located at the City of Arcata wastewater treatment facility adjacent to oxidation pond 1, the same location as the previous TDA experiment.

The filter was a 40-foot long plywood box, with a 2-ft by 2-ft cross section. The box was lined with a reinforced polyethylene fabric and filled with approximately 1,400 pounds of shredded RPC as the filtration media. A 4-inch perforated PVC pipe suspended along the top of media delivered the wastewater influent evenly along nearly the full length of the filter. The wastewater trickled vertically through the shredded RPC media, collected in a drain at one end of the filter, and then flowed by gravity back to the oxidation pond.

The shredded RPC media filter system was run intermittently on a schedule designed to simulate the hydraulic loading of a typical household septic system. The filter was operational from June 27, 2018 until October 15, 2018, receiving influent three, 90-minute periods per day at an approximate rate of 3 GPM. The value of 97 different water quality constituents and characteristics were determined for influent and effluent water samples collected at two to three week intervals during the period of filter operation, resulting in seven sample pairs. The constituents examined included 18 metals, 68 volatile organics, and a variety of conventional wastewater characteristics and constituents.

Ultimately, only 25 of the 97 constituents examined were detected during the sampling. Of the constituents tested, there were very minor increases in the specific conductivity and in the concentration of chloride, magnesium, orthophosphate, sodium, and sulfate. All of the increases in value were less than 5% with the exception of orthophosphate, which increased on average by 17%, largely driven by one sample where the effluent was 40% higher than the influent. Almost all of the remaining 19 detected constituents were greatly reduced by the filter, with removal rates ranging from 20 to 74%.

The shredded RPC media filter compared favorably to other filtration systems treating similar wastewater. The removal rate for metals and conventional wastewater constituents was double to triple that of the best removal rate for a rock aggregate and TDA filter that was the design basis for this filter. The removal rates were either comparable or exceeded those of a slow sand filter treating similar wastewater.

The primary limitation of the shredded RPC media filter was the drain design which required all of the effluent to flow horizontal to a single drain at one end of the container. This feature was deliberately selected to match the design of the rock and TDA filters and facilitate comparison with their performance in a septic tank leach field application. However, the lower hydraulic conductivity of the shredded carpet and the long travel distance to the drain limits the surface loading rate of the wastewater to prevent flooding the system. The high surface area of carpet fibers and the lack of any harmful products leaching from the shredded PET material seem ideal for a vertical flow wastewater filter. Limiting the flow path to a few feet would allow an increase in the surface loading rate which reduces the footprint of the filter for treating a specified daily...
flow volume. It is suggested that future research investigate the removal rates for common wastewater constituents with a vertical flow filter filled with shredded PET carpet. Filters of this configuration are used in onsite wastewater treatment systems, a common situation for homes, small housing units, and small businesses. The tradeoff between constituent removal rates and surface loading rates should be determined, along with the length of the operational period possible before media plugging limits further use.
5 REFERENCES


## APPENDIX A

### List of All Constituents Tested

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Detection limit (DL)</th>
<th>units</th>
<th>Detected?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals by EPA 200 Series Methods</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aluminum</td>
<td>0.02</td>
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</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
<td>mg/L</td>
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</tr>
<tr>
<td>Arsenic</td>
<td>0.004</td>
<td>mg/L</td>
<td>Y</td>
</tr>
<tr>
<td>Barium</td>
<td>0.001</td>
<td>mg/L</td>
<td>Y</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.001</td>
<td>mg/L</td>
<td>N</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.004</td>
<td>mg/L</td>
<td>N</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.002</td>
<td>mg/L</td>
<td>N</td>
</tr>
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<td>Copper</td>
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</tr>
<tr>
<td>Iron</td>
<td>0.05</td>
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</tr>
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<td>Lead</td>
<td>0.02</td>
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<tr>
<td>Magnesium</td>
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<td>mg/L</td>
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<td>Manganese</td>
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<td>Mercury</td>
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</tr>
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<td>Selenium</td>
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<td>Sodium</td>
<td>0.4</td>
<td>mg/L</td>
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<tr>
<td>Zinc</td>
<td>0.008</td>
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<td>Constituent</td>
<td>Detection limit (DL)</td>
<td>units</td>
<td>Detected?</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>----------------------</td>
<td>---------</td>
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<td>1664A)</td>
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<td>Detected?</td>
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<td>----------------------</td>
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<td>Xylenes (total)</td>
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<td>ug/L</td>
<td>N</td>
</tr>
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</table>

*Note: **Unless otherwise stated, test performed by Alpha Analytical Laboratories*
Appendix C – Pilot Study 2: Stormwater Filtration using Recycled PET Carpet Media (Phase II)
Stormwater Filtration using Recycled PET Carpet Media

Prepared by
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Environmental Resources Engineering
1 Harpst Street
Arcata, CA 95521

HUMBOLDT
STATE UNIVERSITY

July 2019
**LIST OF ABBREVIATIONS**

AAL | Alpha Analytical Laboratories  
AI | Aluminum  
BOD | Biochemical Oxygen Demand (5-day)  
CA | California  
CalRecycle | California Department of Resources Recycling and Recovery  
CARE | Carpet America Recovery Effort  
CCSP | California Carpet Stewardship Program  
COD | Chemical Oxygen Demand  
Cu | Copper  
DI | Drop Inlet  
Fe | Iron  
ft | foot or feet  
gm | gram  
HBHRCD | Humboldt Bay Harbor, Recreation and Conservation District  
HSU | Humboldt State University  
kg | kilogram  
L | liter  
MDL | method detection limit  
mg | milligram  
μg | microgram  
N | Nitrogen  
NCL | North Coast Laboratories  
NTU | Nephelometric Turbidity Units  
O&G | Oil and grease – hexane extraction method (HEM)  
PCC | Post-Consumer Carpet  
PFAS | Per- and Polyfluoroalkyl Substances  
PFOA | Perfluorooctanoic acid  
PET | Polyethylene Terephthalate  
PFOS | Perfluorooctane Sulfonate or Perfluorooctanesulfonic acid  
PVC | Polyvinyl Chloride  
RPC | Recycled PET Carpet  
SWPPP | Stormwater Pollution Prevention Plan  
TCLP | Toxic Characteristic Leaching Procedure  
TDA | Tire Derived Aggregate  
TSS | Total Suspended Solids  
US | United States  
VOC | Volatile Organic Compound  
WET | Waste Extraction Test  
Zn | Zinc
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Introduction

California Assembly Bill 2398, enacted in 2010, established the California Carpet Stewardship Program (CCSP). The goal of the CCSP is to provide funding to establish, increase, and improve the collection, recycling, and utilization of California-generated post-consumer carpet (PCC) in recycled-content product manufacturing. The bill designated an organization named Carpet America Recovery Effort (CARE), with oversight from the California Department of Resources Recycling and Recovery (CalRecycle), as the administrator of the CCSP.

CARE has successfully created programs to support the collection and reuse of nylon and polyethylene terephthalate (PET) carpet waste. Recycled PET carpet (RPC) material outlets and diversion streams are not yet at the scale necessary to reuse all the current RPC materials. CARE is promoting research to identify potential uses of RPC materials in civil engineering applications.

As part of a coordinated effort to identify potential reuse streams for RPC material, Humboldt State University (HSU) performed laboratory analyses to determine the density, compressibility, hydraulic conductivity, and porosity values for three forms of RPC products: shredded carpet, face fiber (or “fluff”), and carpet underlayment (carpet “pad”) (Finney et al., 2016). During the laboratory analyses, the concentration of numerous constituents was determined for water saturating RPC for various durations. Leachate water quality results show that RPC material is relatively benign. Additionally, shredded RPC was analyzed by the Toxic Characteristic Leaching Procedure (TCLP) and Waste Extraction Test (WET) protocols, and results indicate that RPC is not considered a hazardous material.

Material property testing conducted by HSU characterized RPC products as lightweight materials with higher porosity but lower hydraulic conductivity when compared to conventional construction materials like soil and gravel. The RPC products examined generally also have high compressibility and high surface area (Finney et al. 2016). When used as a water filter, the high surface area of the materials provides for physical filtering and removal of some water quality constituents and an opportunity for a large attached growth bacteria community to transform some water quality constituents to less harmful forms. Based on a review of the existing literature and these laboratory results, further research was proposed that included three pilot studies for applications of RPC in wastewater and stormwater treatment.

The first pilot study, completed and reported on by Finney et al. (2019) evaluated the use of recycled shredded RPC in an application for wastewater treatment. An above ground filtration system was designed and constructed to evaluate the effectiveness of using shredded RPC as filtration media in septic system leach line drainage for primary treated wastewater. The filter was designed and operated to match an earlier investigation where use of Tire Derived Aggregate (TDA) was compared to conventional rock aggregate as a media in a septic tank leach field setting. Finney et al. (2013) found that TDA performed as well or better than rock aggregate in treating septic tank effluent with the improved performance theorized to be related to the higher surface area of the TDA media compared to the rock aggregate. The shredded RPC filter compared favorably to other filtration systems treating similar wastewater. The removal rate for metals and conventional wastewater constituents was double to triple that of the best removal rate for a rock aggregate and TDA filter that was the design basis for this filter. The removal rates were either comparable or exceeded those of a slow sand filter treating similar wastewater (Finney et al. 2019).
The primary limitation of the shredded RPC filter was the drain design which required all of the effluent to flow horizontal to a single drain at one end of the container. The low hydraulic conductivity of the shredded carpet and the long travel distance to the drain limits the surface loading rate of the wastewater to prevent flooding the system. Finney et al. (2019) recommended additional research with a vertical flow wastewater filtration design that limits the flow path to a few feet allowing an increase in the surface loading rate, thereby reducing the footprint of the filter for treating a specified daily flow volume.

This report addresses additional pilot projects initiated to study the use of RPC as a filtration media in stormwater treatment applications. A key difference in these pilot studies is the form of the RPC. Rather than shredded carpet, the filter media used in the stormwater applications was a flat pad that was made from the RPC. The RPC pad was used as a filtration media in three ways: 1) the media was placed in drop inlets and the stormwater flowed through the material, 2) the media was placed directly on the ground and stormwater sheet flow moved along the surface of the media, and 3) the media was rolled and enclosed by netting, similar to straw wattles, and stormwater flowed through the material (Figure 1). The RPC media was installed at sites that were using landscape fabric drop cloths and straw wattles to control and treat stormwater. The RPC material has a very high surface area to volume ratio which provides additional opportunities for physical and biological treatment of water flowing through it compared to plant-based alternatives. In addition, RPC material may have a longer useful life and contribute less organic loading in use compared to existing materials.

Figure 1 RPC material used in stormwater applications - the flat pad and a rolled wattle.
Experimental Set-up and Sampling Methodology

Given the complexity of evaluating stormwater data and the limitations with obtaining representative samples from pre and post stormwater treatment, a multi-pronged approach was undertaken to evaluate the effectiveness of the RPC pad in stormwater treatment. This included laboratory leaching experiments, field site experiments where runoff characteristic of a site was collected and brought back to the lab for filtration lab experiments, and field site experiments where stormwater was sampled pre and post treatment.

Laboratory Leaching Experiments
Prior to on-site installation, laboratory chemical analyses of the leachate from the carpet pad were conducted to determine whether undesirable constituents might be contributed to the stormwater from the RPC material itself. Five experiments were conducted including two soak tests, a sequential soak test, and two flow-through tests. Water quality analyses were conducted for constituents that are typically included in stormwater permits. These constituents include various metals, total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), oil and grease (O&G), nutrients, and specific conductance.

The first experiment was conducted to verify that the constituents that would leach from the RPC pad were essentially the same as previously identified by Finney et al. (2016). A four day soak test was conducted on a randomly selected roll of RPC pad. A strip weighing 623-g was cut from the roll and placed in a 9-L Pyrex jar. The strip of pad was submerged with 8.4-L of distilled water and left to soak at room temperature with the jar covered (Figure 2). After four days, the pad was allowed to gravity drain prior to collecting leachate samples. The leachate samples were sent to Alpha Analytical Laboratories (AAL) for chemical analysis. Given the artificial nature of the experiment with such a large ratio of RPC pad mass to water and the long soak time, the concentration of the constituents in the leachate would be higher than expected in an actual stormwater treatment application. However, a conservative assessment of the risk of contributing to a stormwater discharge permit violation if the material was used in a treatment system can be made by comparing the leachate concentrations to Numeric Action Limits (NAL) in the California NPDES general permit for stormwater discharges from industrial activities.

A second soaking experiment was conducted to determine the extent that BOD and COD concentrations in RPC pad leachate were reduced following a first flush or rinse. A 633-g sample from a separate randomly selected carpet pad roll was initially soaked for five days in distilled water at room temperature. The pad pore water was gravity drained and samples of the “first pass” leachate were collected. Filtered and unfiltered samples were sent to North Coast Laboratories (NCL) for BOD analysis and AAL for COD analysis. The jar was drained and then refilled with distilled water and the same strip of RPC pad allowed to soak at room temperature for two more days before the “second pass” leachate was removed. Filtered and unfiltered samples were sent to NCL and AAL for BOD and COD analysis, respectively.

COD is a common constituent of concern in stormwater runoff, and previous research by Finney et al. (2016) indicated that leachate from the initial flush of RPC materials contains COD. Therefore a third experiment was conducted to examine the COD leached from a wattle made from RPC pad under simulated stormwater conditions. A short section of a wattle was placed in a flume and water was sent through the channel (Figure 2). Water samples were collected upstream of the wattle, and downstream immediately after the flow passed through the material, after two minutes of consistent flow, and then again after 18 minutes of consistent flow. The wattle was then removed from the flume, submerged in tap water for several minutes, and placed back in the flume. Water was sent through the channel, and additional samples were
obtained upstream of the wattle, downstream immediately after the flow began, after two minutes, and after 18 minutes. The COD concentration in the samples was determined by NCL.

A final set of two experiments were conducted to investigate the presence of two per- and polyfluoroalkyl substances (PFAS), Perfluorooctanoic (PFOA) and Perfluorooctanesulfonic acid (PFOS), in the leachate from RPC shreds and pad. While outside of the initial project scope, the testing was suggested by the client towards the end of the study. In the first experiment, separate samples of RPC shred and pad were soaked for eight days in distilled water and the leachate was sampled for PFOA and PFOS. The second experiment was designed to simulate the situation of a new RPC media filter experiencing its first runoff event. In this experiment, 8-L of distilled water was poured through RPC shred and pad contained in a colander and again the leachate was sampled for PFOA and PFOS. Leaching experiments are summarized in Table 1.

Figure 2 RPC pad in distilled water on the first day of soaking (left). RPC pad wattle in the flume (right).
Table 1 Summary of Leaching Experiments

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Length of Experiment</th>
<th>Material Tested</th>
<th>Constituents Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soaked in distilled water</td>
<td>4 days</td>
<td>Strip of RPC pad</td>
<td>oil and grease, metals, nutrients, VOCs, turbidity, EC, TSS, and COD</td>
</tr>
<tr>
<td>Sequential soak in distilled water</td>
<td>7 days</td>
<td>Strip of RPC pad</td>
<td>BOD and COD</td>
</tr>
<tr>
<td>Flow-through - initial</td>
<td>2 minutes 18 minutes</td>
<td>RPC wattle</td>
<td>COD</td>
</tr>
<tr>
<td>Flow-through – drained after first run</td>
<td>2 minutes 18 minutes</td>
<td>RPC wattle</td>
<td>COD</td>
</tr>
<tr>
<td>Soaked in distilled water</td>
<td>8 days</td>
<td>RPC shred RPC pad</td>
<td>PFOA/PFOS</td>
</tr>
<tr>
<td>Pour through with distilled water</td>
<td>2 minutes</td>
<td>RPC shred RPC pad</td>
<td>PFOA/PFOS</td>
</tr>
</tbody>
</table>

Combined Field Site and Laboratory Filtration Experiments
A publically-owned boat repair and storage facility and a privately-owned rural parcel were identified as field test sites for pilot applications of RPC pad to treat stormwater. The layout and stormwater characteristics of each site determined the stormwater treatment measures implemented and the methods used to evaluate the effectiveness of those measures. RPC pad was used in flat sheet flow-through, flat sheet flow-over, and rolled sheet (wattle) flow-through applications. The effectiveness of the measures were evaluated by visual observations, collecting samples pre and post treatment in the field, and collecting pre treatment samples in the field followed by laboratory experiments approximating post treatment conditions. The boat repair yard had the greatest opportunity for implementing treatment measures and the facility and experimental procedures implemented at this site are described in detail in the section below. A brief section describing the experimental procedure implemented at the privately-owned rural parcel follows in the subsequent section.

Fields Landing Boat Yard
The Fields Landing Boat Yard is owned and operated by the Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD). The boat yard is an open air storage facility located in the South Bay of Humboldt Bay in close proximity to the harbor entrance (Figure 3). The facility accommodates boat storage and maintenance year round for recreational and commercial vessels up to 100 feet in length. There is an indoor facility on site that can accommodate boats up to 80 feet in length, however most boat maintenance and repair work is done in the 3.75 acre (15,000 m²) asphalt paved open yard (Figure 4) (HBHRCD 2019).
Figure 3 Location of Fields Landing Boat Yard.
Figure 4 Layout of the experimental site at the Humboldt Bay Harbor, Recreation, and Conservation District Fields Landing Boat Yard. Primary cleaning and maintenance areas are highlighted as well as the drop inlet where most the boat yard runoff collects. (Photo courtesy of Google Earth).

Given the proximity to Humboldt Bay, the HBHRCD has a Stormwater Pollution Prevention Plan (SWPPP) to treat both wash water from boat cleaning activities and the stormwater runoff from the site. Most of the paved area drains to the stormwater drop inlet (DI) shown in Figure 4. There are three main measures used to control and treat runoff. Drop clothes are placed under
the boats during washing and maintenance to retain larger solids (Figure 5). Boat wash water is collected at the drop inlet and pretreated on site before being transported off site for final treatment and disposal (Figure 6). During precipitation events, water entering the DI is discharged into the drainage ditch and then into Humboldt Bay. Some portions of the facility however drain directly to either the drainage ditch or Humboldt Bay, so wattles are placed around the perimeter of the paved portion of the site to retain windblown solids onsite and filter water running off the site (Figure 7).

![Figure 5 Drop cloth used as ground cover below boat washing and maintenance areas.](image)
Figure 6 Drop inlet that drains runoff from paved surfaces at the Fields Landing Boat Yard. Note the old straw wattles around the secondary drain to the left.

Figure 7 Straw wattles used to control stormwater and wash water runoff from the Fields Landing Boat Yard.
RPC media was substituted for the existing material used in all three stormwater control measures. RPC pad material was used to replace the landscape fabric drop cloths placed under the boats during boat maintenance (Figure 8). The RPC drop cloths are thicker than the previous fabric and have a rougher surface to collect and trap dust and particulates. They also have the potential to provide additional biological treatment given the higher surface area.

A layer of the RPC pad material was placed in the drop inlet (Figure 4, Figure 6Error! Reference source not found.) to filter water as it drained from the paved surfaces and before it was either discharged (stormwater) or collected for treatment (wash water). The filter was replaced periodically.

Wattles containing RPC pad material were assembled and used to replace 1,300 feet (396 meters) of straw wattles around the perimeter of the paved site (Figure 9). The 6-ft wide RPC pad material was cut into 6-ft long pieces, rolled up, and placed in durable poly mesh netting. The wattles were secured in place with zip ties and surveyor spikes (Figure 10).
Figure 9 Fields Landing Site Layout showing location of wattle placement. (Photo courtesy of Google Earth).
Figure 10 Wattles filled with RPC media along perimeter fence of Fields Landing Boat Yard.

The RPC stormwater filter measures were installed in September of 2018 and remained in use through June 2019. Stormwater and wash water samples were collected at various areas on site including at the drop inlet and directly from the ground surface (Figure 11). The samples collected from the ground surface were obtained using a small hand-operated pump (Figure 12).

Due to difficulties in collecting representative samples post treatment, water samples were collected and analyzed to characterize the quality of the runoff associated with the runoff from storm events as well as the water quality from specific site activities such as boat washing (Table 2).
Figure 11 Sample locations at Fields Landing Boat Yard. (Photo courtesy of Google Earth).
Figure 12 Sample pump used to pull water from ground surface.

Table 2 Sample collection at Fields Landing Boat Yard

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>Sample Location</th>
<th>Sample Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/7/2018</td>
<td>Directly under boat</td>
<td>Boat wash water directly off boat</td>
</tr>
<tr>
<td>11/7/2018</td>
<td>Asphalt prior to drop inlet</td>
<td>Boat wash water running off pad and ~ 8 feet of asphalt</td>
</tr>
<tr>
<td>3/22/2019</td>
<td>Various locations (6)</td>
<td>Site runoff sample during storm event</td>
</tr>
<tr>
<td>4/5/2019</td>
<td>Various locations (7)</td>
<td>Site runoff sample during storm event</td>
</tr>
<tr>
<td>5/3/2019</td>
<td>Directly under boat</td>
<td>Boat wash water directly off boat</td>
</tr>
<tr>
<td>5/3/2019</td>
<td>Asphalt prior to drop inlet</td>
<td>Boat wash water running off pad and ~ 20 feet of asphalt</td>
</tr>
</tbody>
</table>

**Laboratory RPC Filtration**

The boat wash water sample collected in May 2019 was brought back to the Humboldt State University lab to determine the effectiveness of the filtration measures on site. Four post treatment samples were prepared where each sample was filtered through one to four layers of RPC pad material (Figure 13).
The constituents identified for sampling and analysis were consistent with requirements identified in the site SWPPP (SHN 2019) and included those listed in Table 3. State certified analytical labs determined the value of the water quality constituents and characteristics for each sample.

Table 3 Constituents analyzed in laboratory and field filtration samples.

<table>
<thead>
<tr>
<th>Metals</th>
<th>aluminum, copper, iron, zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other parameters</td>
<td>pH, oil &amp; grease, TSS</td>
</tr>
</tbody>
</table>

For two events, it was possible to evaluate the effectiveness of treatment measures directly from field samples. Water samples were collected during two different events when boats were being washed. The water dripping directly off the boat during washing was collected and represented a pre treatment sample and water running off the RPC pad below the boat was collected and represented a post treatment sample.

**Privately owned rural parcel**
The second field site was at a privately-owned unpaved facility with stormwater runoff constituents typical for construction and land uses in the rural Pacific Northwest. At this site, two existing bioswales were lined with the RPC pad and RPC media wattles were placed at the end
of the swale prior to a small sediment pond (Figure 14). A pre treatment sample was collected upstream of a channel lined with the carpet pad. The post treatment sample was collected downstream of the lined channel and wattle installation (Figure 14). Samples were collected during two storm events that occurred on December 14, 2018 and January 31, 2019. The same constituents listed in Table 3 were analyzed with the exception of copper and aluminum.

Figure 14 RPC filter media in channel immediately after installation (October 2018).
Stormwater Filtration using Recycled PET Carpet Media

Summary of Experimental Results

Results from the analysis of the samples collected from the experiments described in the previous section are presented. The results are organized as 1) laboratory leaching and flow-through experiments excluding those for PFAS, 2) characterization of the Fields Landing Boat Yard runoff, 3) laboratory filtration experiments with field samples representative of typical boat wash water runoff, 4) laboratory analyses of field samples collected pre and post stormwater treatment, 5) visual characterization of durability of the RPC material under field conditions and 6) laboratory leaching and flow-through experiments specifically for PFAS.

Laboratory Leaching and Flow-Through Experiments (excepting PFAS)
The results from the first leaching experiment where the carpet pad was left to soak for four days at room temperature showed that with the exception of COD and magnesium, all constituents included in the California NPDES general permit for stormwater discharges from industrial activities had values less than the corresponding NAL for that constituent, and many cases less than the method detection limit (MDL) (Table 4). A few constituents such as mercury that do have NALs were not included in the constituents tested because previous results of a similar experiment by Finney et al. (2016) showed they were not present in RPC pad leachate. Table 4 also includes the concentration and mass per unit mass of RPC pad for additional constituents examined that were detected in the leachate. With the exception of COD and magnesium, the results from this experiment suggest that leachate from RPC pad used for stormwater treatment is unlikely to be responsible for permit violations. The concentration of COD and magnesium in the leachate was substantially above the NAL value (480 mg/l and 1.8 mg/l vs. 120 mg/l and 0.064 mg/l respectively), but in an actual field application, the leachate concentration would be much more dilute and the pulse of COD and magnesium may be primarily associated with the first flush of the material. The concentration of zinc in the leachate was 0.2 mg/l which is close to the worst case NAL value of 0.26 mg/l, but the leachate concentration should be significantly lower in an actual field application.

The second leaching experiment was conducted to determine whether the BOD and COD in the leachate from subsequent soakings would be significantly reduced following an initial soaking. An 80% decrease in COD and a 70% decrease in BOD resulted from one soak and drain cycle of the RPC pad material (Table 5). The small difference in concentrations between filtered and unfiltered leachate samples indicates that most of COD and BOD is soluble which suggests that a continued reduction in concentrations would likely result from additional soak/drain cycles.
Table 4 Analyte values in RPC pad leachate compared to NAL for the California NPDES general permit for stormwater discharges from industrial activities.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Result</th>
<th>Detection Limit</th>
<th>NAL (^1)</th>
<th>mass/mass RPC pad (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>µg/L</td>
<td>11</td>
<td>0.9</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>0.12</td>
<td>0.02</td>
<td>0.75</td>
<td>1.62</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>1.5</td>
<td>0.1</td>
<td>2.14</td>
<td>20.3</td>
</tr>
<tr>
<td>Antimony</td>
<td>mg/l</td>
<td>0.23</td>
<td>0.006</td>
<td>3.11</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>ND</td>
<td>0.004</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>mg/l</td>
<td>0.0052</td>
<td>0.001</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>ND</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>ND</td>
<td>0.001</td>
<td>0.0053**</td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>mg/l</td>
<td>480</td>
<td>9</td>
<td>120</td>
<td>6480.</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/l</td>
<td>31</td>
<td>1</td>
<td>419.</td>
<td></td>
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<tr>
<td>Chromium</td>
<td>mg/l</td>
<td>ND</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>mg/L</td>
<td>0.0044</td>
<td>0.002</td>
<td>0.06</td>
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</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>ND</td>
<td>0.014</td>
<td>0.0332**</td>
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</tr>
<tr>
<td>Cyanide</td>
<td>mg/L</td>
<td>ND</td>
<td>0.022</td>
<td></td>
<td></td>
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<tr>
<td>Iron</td>
<td>mg/L</td>
<td>0.12</td>
<td>0.05</td>
<td>1</td>
<td>1.62</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>ND</td>
<td>0.02</td>
<td>0.262**</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>1.8</td>
<td>0.03</td>
<td>0.064</td>
<td>24.3</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/l</td>
<td>0.031</td>
<td>0.006</td>
<td>0.42</td>
<td></td>
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<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>ND</td>
<td>0.0014</td>
<td>0.0014</td>
<td></td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>µg/L</td>
<td>3</td>
<td>0.7</td>
<td>0.04</td>
<td></td>
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<tr>
<td>Nickel</td>
<td>mg/l</td>
<td>ND</td>
<td>0.003</td>
<td>1.02**</td>
<td></td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>mg/L as N</td>
<td>ND</td>
<td>0.04</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>Oil &amp; Grease (HEM)</td>
<td>mg/L</td>
<td>2.8</td>
<td>1.4</td>
<td>15</td>
<td>37.8</td>
</tr>
<tr>
<td>Phosphorus, Total</td>
<td>mg/L as P</td>
<td>1.73</td>
<td>0.1</td>
<td>2</td>
<td>23.6</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
<td>ND</td>
<td>0.008</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>mg/L</td>
<td>ND</td>
<td>0.004</td>
<td>0.0183**</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/l</td>
<td>54</td>
<td>0.4</td>
<td>720.</td>
<td></td>
</tr>
<tr>
<td>Specific Conductance (EC)</td>
<td>umhos/cm</td>
<td>400</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfate as SO₄</td>
<td>mg/l</td>
<td>44</td>
<td>2</td>
<td>594.</td>
<td></td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>mg/L</td>
<td>22</td>
<td>0.3</td>
<td>100</td>
<td>297.</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>12</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.2</td>
<td>0.008</td>
<td>0.26**</td>
<td>2.70</td>
</tr>
</tbody>
</table>

**The NAL is the highest value used by U.S. EPA based on a hardness table

\(^1\) California State Water Resources Control Board (2014)
Table 5 COD and BOD concentrations in filtered and unfiltered samples from a un-rinsed ("First pass") and rinsed ("Second pass") RPC pad sample.

<table>
<thead>
<tr>
<th>Sample</th>
<th>BOD (mg/L)</th>
<th>COD (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtered</td>
<td>First Pass</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Second Pass</td>
<td>38</td>
</tr>
<tr>
<td>Unfiltered</td>
<td>First Pass</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Second Pass</td>
<td>39</td>
</tr>
</tbody>
</table>

The flow-through wattle experiment was designed to determine the magnitude of leaching of COD from RPC pad under simulated field conditions. Although it was impossible to determine the fraction of flow that passed through compared to under or over the wattle, it was clear that there was some flow through the wattle. The concentration of COD in all samples downstream of the wattle constructed with RPC pad was below the detection limit of 5 mg/l.

The first two leaching experiments suggest that for the constituents examined, there would only be a concern about the significant contribution of COD, magnesium and possibly zinc from the RPC pad. The concentration of COD in the initial soaking leachate was above the NAL 120 mg/l value of the California NPDES general permit for stormwater discharges from industrial activities (Table 4), but less than the NAL in the second soak/drain cycle, and was not detected in the flow-through experiments. These results suggest there will likely be no significant contributions of COD, magnesium, and zinc from RPC pad in a typical stormwater treatment application.

**Characterization of Fields Landing Boat Yard Stormwater Runoff**

Collecting stormwater samples post treatment at the Fields Landing Boat Yard was difficult, so the potential benefit of RPC media filtration was estimated using laboratory filtration results once typical stormwater runoff quality was known. Runoff was collected at four different points during two precipitation events. In some cases, two samples were collected at a site and the results averaged for that storm. Constituents included in the analysis included those specific to the SWPPP for the facility along with a few additional ones of interest.

The results from the two storms were averaged and compared (where appropriate) to the NAL for the facility (Table 6). The concentrations from the Ramp site were generally much lower than the other sample sites. This site has a small drainage area devoid of any stored boats, and the material responsible for the constituents measured would either be small solids blown to that area of the yard, or dripping from boats as they are hauled out of the water (Figure 11). The East fence sample site drainage area is the small adjacent parking area, the roof of the large adjacent metal building, and overflow from the area surrounding the DI sample point. The concentrations of the measured constituents at this site were nearly all higher than the Ramp site, but lower than the remaining two sites (North fence and DI).

Given the characteristics of their drainage areas, it is not surprising that the concentrations at the North fence and DI site were the highest of the sample sites, and with the exception of aluminum, higher than the applicable NAL. The North fence drainage area included a large number of old boats in long term storage, mostly in poor repair and many waiting to be salvaged. The area also has a large assortment of uncovered metal debris that is heavily oxidized. The DI drainage area includes the boat washing and maintenance area and a portion
of the metal roofed buildings. A considerable reduction in copper, iron and zinc concentrations would be required at these two sites to reduce the values below the NALs. For example, at the DI site, a 98%, 43%, and 72% reduction in the observed values would be required to reach the NAL values for copper, iron and zinc, respectively. This high level of removal may be difficult to meet with simple filtration since a significant fraction of the metals appear to be in the dissolved state. The dissolved fraction for copper ranged from 25% to 50%, and for zinc it ranged from 66% to 78% (Table 6).

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Numeric Action Limits</th>
<th>DI</th>
<th>North Fence</th>
<th>East Fence</th>
<th>Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al (mg/l)</td>
<td>0.75</td>
<td>0.57</td>
<td>0.63</td>
<td>0.60</td>
<td>0.083</td>
</tr>
<tr>
<td>Cu (mg/l)</td>
<td>0.033</td>
<td>2.35</td>
<td>0.77</td>
<td>0.25</td>
<td>0.055</td>
</tr>
<tr>
<td>Cu dissolved (mg/l)</td>
<td></td>
<td>0.61</td>
<td></td>
<td></td>
<td>0.023</td>
</tr>
<tr>
<td>Fe (mg/l)</td>
<td>1.0</td>
<td>1.74</td>
<td>2.75</td>
<td>1.25</td>
<td>0.15</td>
</tr>
<tr>
<td>Zn (mg/l)</td>
<td>0.26</td>
<td>0.94</td>
<td>0.31</td>
<td>0.13</td>
<td>0.18</td>
</tr>
<tr>
<td>Zn dissolved (mg/l)</td>
<td></td>
<td>0.62</td>
<td></td>
<td></td>
<td>0.14</td>
</tr>
<tr>
<td>O&amp;G (mg/l)</td>
<td>15</td>
<td>5.7</td>
<td>4.4</td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>100</td>
<td>37</td>
<td>23</td>
<td>45</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Laboratory Filtration Experiments with Boat Wash Water Runoff**

To estimate the performance of the RPC pad for treating runoff from boat washing activities at the Fields Landing Boat Yard, a sample of water dripping directly off the boat while it was being cleaned was taken. The concentration of the constituents measured was much higher (several orders of magnitude) than that of the stormwater from the facility (Table 7). Most of the metal appears to be in the particulate form, with the dissolved fraction of copper and zinc being 3% and less than 1% respectively.

A single layer of RPC pad removed over 70% of the copper and zinc from the wash water, and increasing the number of layers of mat resulted in a small, but increasing fractional removal (Figure 15). With four layers of the pad used as a filter, over 80% of the copper and zinc were removed from the wash water runoff. The removal rates for the other metals tested started much lower, at 7% and 17% for aluminum and iron respectively when filtering through a single layer of the pad (Figure 15). However, the increase in percent removal for those metals was higher than for copper and zinc as the number of layers of pad increased. With four layers of the pad used as a filter, over 50% of the aluminum and 60% of the iron were removed from the wash water runoff.
The removal of TSS does not correspond to the removal rates of copper and zinc (Figure 15). Since these two metals are the largest mass fraction of the metals examined, it is clear that there are additional components of the wash water runoff that contribute to the solids load besides the metals examined. The rate of removal and the change in the rate for aluminum and iron as the number of layers of pad increased closely mirrors the removal of TSS suggesting that the particle sizes of the remaining solids components are similar to that of those two metals particles.

The relatively high rate of removal of copper and zinc with just a single layer of the RPC pad suggests that those metals are contained in larger sized solids that are easily filtered. The RPC pad filters appeared to have little impact on the dissolved cooper and zinc (Figure 16, Figure 17). This result may indicate the RPC pad is only suitable for the removal of runoff constituents that are either in a particulate form or are sorbed onto a filterable particle.

Table 7 Characteristics of boat wash water sample used for filtration experiment

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Al</th>
<th>Cu</th>
<th>Cu dissolved</th>
<th>Fe</th>
<th>Zn</th>
<th>Zn dissolved</th>
<th>TSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration (mg/l)</td>
<td>10</td>
<td>170</td>
<td>5.8</td>
<td>18</td>
<td>59</td>
<td>0.4</td>
<td>840</td>
</tr>
</tbody>
</table>
Figure 15 Fractional removal of boat wash runoff constituents by layers of RPC pad.
Figure 16 Relationship between the number of RPC pad layers used and the effluent total and dissolved copper concentration of filtered boat wash water runoff.

Figure 17 Relationship between the number of RPC pad layers used and the effluent total and dissolved zinc concentration of filtered boat wash water runoff.
Field Samples Collected Pre and Post Runoff Treatment
Fields samples of runoff were collected pre and post treatment with RPC pad at both the Fields Landing Boat Yard and the privately-owned rural site. The boat yard sample was collected on 5/3/2019 from a boat that was being cleaned. The boat was on jack stands and the entire area under the boat was covered by a single layer of RPC pad. The pre treatment wash water runoff was collected as it dripped directly off the boat. Post treatment runoff was collected after the water traveled through the pad and then over approximately 30 feet of asphalt. While there was no effect on oil and grease and dissolved metals, the removal rates for total metals and TSS were impressive. Removal rates from the RPC pad treatment ranged from 62% for aluminum and iron to 92% for zinc (Table 8) which is greater than observed by four layers of the pad material in the laboratory filtration experiment on the same wash water runoff (Figure 15).

Table 8 Boat wash water runoff quality pre and post RPC pad treatment

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Wash water leaving boat</th>
<th>Runoff from pad</th>
<th>Fraction Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al (mg/l)</td>
<td>10</td>
<td>3.8</td>
<td>0.62</td>
</tr>
<tr>
<td>Cu (mg/l)</td>
<td>170</td>
<td>28</td>
<td>0.83</td>
</tr>
<tr>
<td>Cu dissolved (mg/l)</td>
<td>5.8</td>
<td>8.5</td>
<td>-</td>
</tr>
<tr>
<td>Fe (mg/l)</td>
<td>18</td>
<td>6.8</td>
<td>0.62</td>
</tr>
<tr>
<td>Zn (mg/l)</td>
<td>59</td>
<td>4.8</td>
<td>0.92</td>
</tr>
<tr>
<td>Zn dissolved (mg/l)</td>
<td>0.4</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>O&amp;G (mg/l)</td>
<td>4</td>
<td>4.2</td>
<td>-</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>840</td>
<td>280</td>
<td>0.67</td>
</tr>
<tr>
<td>pH</td>
<td>7.3</td>
<td>7.5</td>
<td></td>
</tr>
</tbody>
</table>

Pre and post treatment stormwater runoff samples were also collected during two rainfall events from the privately-owned rural parcel. The pre treatment samples were collected in a bioswale just upstream of the point where the channel was lined with RPC pad, and the post treatment sample was collected just downstream of the 45-foot long lined section and a RPC wattle. The combination of these two treatment measures was very effective for TSS, COD, iron and zinc. During the first event, removal rates ranged from 59% for iron and zinc, to 69% for COD. In the second runoff event, solids were at a much higher concentration and the TSS removal rate was 75%, while the removal rate for the other constituents was just slightly less than observed during the first sample event. Photos taken of the channel after the second sample event clearly show significant sediment deposition on the RPC pad which may be largely responsible for the TSS and total metals removal (Figure 18).
Table 9 Stormwater runoff quality pre and post RPC pad lined channel and wattle treatment

<table>
<thead>
<tr>
<th>Constituent</th>
<th>12/14/2018</th>
<th>4/5/2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before control (mg/l)</td>
<td>After control (mg/l)</td>
</tr>
<tr>
<td>TSS</td>
<td>1,400</td>
<td>450</td>
</tr>
<tr>
<td>O&amp;G</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>COD</td>
<td>710</td>
<td>220</td>
</tr>
<tr>
<td>Fe</td>
<td>140</td>
<td>58</td>
</tr>
<tr>
<td>Zn</td>
<td>0.32</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Visual Characterization of RPC Material Durability under Field Conditions

For this project, RPC pads were used as drop cloths under boats while they were being cleaned and maintained, as a sheet filter in a drop inlet, as a lining for stormwater bioswales, and rolled up as stormwater control wattle. As drop cloths, the pad was used for a single boat cleaning and then discarded due to the heavy accumulation of solids typically scrubbed off the boat. While the pads were saturated with water and received heavy foot traffic during use, there was little evidence of any substantial tearing or degradation prior to their disposal. The sheet of RPC pad
placed in the stormwater DI as a filter at the boat yard was replaced several times per month depending on amount of solids that had accumulated on the pad. Again, there was no evidence of any degradation of the pad prior to being replaced.

The RPC pad in the wattles installed at both the boat yard and the privately-owned rural facility in August 2018 appears to be in nearly perfect condition in June 2019 after spending nine months out in the sun and rain, and the wattles should be able to be used for several more years (Figure 19). Previous experience at both of these locations indicates a typical useful lifespan of straw wattles to be a single wet season. The RPC pad used to line the bioswale at the privately-owned rural facility did suffer some damage during the 9 months it was out in the weather. The primary damage is due to solids deposition and weeds growing up through small holes made in the pad during installation (Figure 19, Figure 20). However, the pad could be used another year prior to disposal.

**PFAS Laboratory Leaching and Flow-Through Experiment Results**

The experiments for PFOS and PFOA suggested by CARE near the end of this study indicate that detectable concentrations of these constituents are leaching from RPC products into water under both soaking and flow-through conditions (Table 10). Nearly all of the concentrations observed exceeded the USEPA drinking water health advisory value of 0.07 μg/l for both compounds (USEPA 2016a, USEPA 2016b). These results indicate further analysis of the rate and duration of PFOA and PFOS leaching from RPC under actual field conditions must be conducted before the suitability of this material for use in stormwater treatment can be determined.

### Table 10 Summary of Leaching Experiments for PFOS/PFOA

<table>
<thead>
<tr>
<th>Material</th>
<th>Experimental conditions</th>
<th>Perfluorooctanesulfonic acid</th>
<th>Perfluorooctanoic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Leachate concentration (μg/l)</td>
<td>Per unit mass of carpet material (μg/kg)</td>
</tr>
<tr>
<td>RPC Shred</td>
<td>8 day soak in 9L water</td>
<td>0.58</td>
<td>6.4</td>
</tr>
<tr>
<td>RPC Shred</td>
<td>8L water poured over material</td>
<td>0.081</td>
<td>2.2</td>
</tr>
<tr>
<td>RPC pad</td>
<td>8 day soak in 8.9L water</td>
<td>0.63</td>
<td>7.6</td>
</tr>
<tr>
<td>RPC pad</td>
<td>8L water poured over material</td>
<td>0.029</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Figure 19 Debris covered RPC wattle installed at the privately-owned rural parcel after a year of use (top), and shaken off (bottom).
Figure 20 Silt covered RPC pad with weeds growing through small holes.
Summary and Conclusion

The experiments conducted during this project yield insights into the potential effectiveness of RPC media in stormwater treatment applications. An evaluation of the RPC media was conducted under a range of conditions and applications that included laboratory experiments simulating worst case scenarios for leaching, laboratory filtration experiments using water samples collected from pilot field sites, and analysis of pre and post treatment of stormwater collected directly from pilot sites.

Laboratory leaching experiments indicate that COD, magnesium, and to a lesser extent zinc may leach off the RPC material under extreme conditions in high enough concentrations to lead to potential violations of typical stormwater permit limits. Extreme conditions include multiple days of soaking and first flush type events. The laboratory experiments show significant reductions in COD and BOD (62-80%) after the first exposure. Laboratory flow-through experiments that mimic likely field conditions indicate non-detectable levels of COD.

Laboratory filtration experiments with boat wash water from the Fields Landing Boat Yard indicate metals are reduced by 54-69% via filtration with RPC pad. Copper and zinc are most effectively removed (70-80+) and aluminum and iron are less effectively removed (< 20% with one layer of RPC filter). Increasing the layers of RPC pad resulted in increased reduction for aluminum and iron and with four layers over 50% of all metals tested was removed. Dissolved metals (copper and zinc specifically) were not reduced and in some cases increased with RPC pad filtration, however, dissolved metals are a very small fraction of the boat wash water.

Stormwater samples collected at the Fields Landing Boat Yard and analyzed for constituents that would typically be monitored by a SWPPP indicated concentrations that are significantly higher than the NAL. Stormwater control measures would have to reduce common metals such as copper, iron, and zinc by 40 to 100%. Stormwater sample analysis also indicate a significant fraction of the metals are in a dissolved state (25-78%) and thus stormwater control measures based on filtration alone may not be enough to effectively meet NALs.

Although these results are encouraging, the results from the filtration experiments from the boat wash water cannot be directly extrapolated to the stormwater due to differences in the water quality. The stormwater contained lower concentrations of constituents and higher fractions of constituents in the dissolved phase.

The RPC media applications evaluated in the field by collecting samples of sediment rich stormwater before and after water traveled through the RPC media showed effective reductions of 50-92% in BOD, COD, and TSS. The stormwater control measures using the RPC materials held up well over a storm season, exhibiting little sign of degradation. The use of the RPC materials is particularly promising in the rolled wattle form where there is a need for long term use over multiple years rather than a single construction season. The RPC wattles have a longer design life than wattles made from straw and do not break down to contribute to organic loading. The RPC media is most effective for the control of BOD, COD, and TSS and constituents such as copper and zinc that are attached to particulates.

Despite these promising results, and those of the companion study on the use of RPC shred for wastewater treatment, additional research must be conducted before the suitability of this material for use in storm or wastewater treatment can be determined. Based on this studies detection of PFOA and PFOS in the water used to soak RPC in exceedance of the USEPA drinking water heath advisory value, it is recommended that further research on the rate and
duration of PFOA and PFOS leaching from RPC material applications be completed before the use of RPC materials in water contact environments are implemented.
References


Appendix D – Microplastics Memo
1. **Purpose**

This memorandum was written to address questions arising from a peer review of proposed research to study the feasibility of using polyethylene terephthalate (PET) carpet fibers in civil engineering applications. Potential applications considered are infiltration galleries for stormwater retention and septic system leach fields. The concern raised is that PET carpet fiber, if used in these ways, may introduce microfibers to groundwater or soil, and be subject to current or future pollution control regulation under California law. Specific questions that are addressed herein include:

- What are microplastics and what is the concern?
- What is the potential for PET fibers used in the proposed applications to leach microplastics to the subsurface environment?
- What is known about the interaction of such particles with soils?
- Is there existing or proposed regulation in California by which the release of microparticles by this route could be regulated?
- How are microplastics measured and treated?
2. Microplastics: Definitions and Context

Microplastics and nanoplastics are terms used to describe plastic pollution that is very small in size. Exact definitions vary by author, although *microplastics* is commonly used for particles smaller than 5 millimeters (mm) but larger than 1 micrometer (µm), while *nanoplastics* generally refers to plastic particles with dimensions smaller than 1 µm.¹,² For this report, the term *microplastics* will be used for both.

The initial reports of microplastics in the ocean date back to the 1970s. However a landmark 2004 article pointing to these pollutants as a potential environmental concern accelerated research interest, and to date there have been an estimated 600 research articles published on the topic.³,⁴ Microplastics have received increased attention in the past decade due to numerous reports of their large-scale occurrence in a variety of environmental media and scientific uncertainty as to their toxicological relevance.¹,⁵

Microplastics have been observed in a variety of chemical forms, including polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET).⁶ They are further categorized as being “primary” or “secondary”.²,⁷ Primary microplastics were designed to be microscopic, and include engineered plastic microbeads used in personal care products, industrial abrasives, drug delivery agents, and pellets or powders. Secondary microplastics result from the breakdown of plastic products that were manufactured as larger items. Secondary microplastics also include microfibers, which can be separated from synthetic fabrics during machine washing. Secondary microplastics are degraded mechanically, chemically and biologically, in myriad processes that are poorly understood.²,⁵ Figure 1 shows example images of primary and secondary microplastics.⁷
Figure 1. Images of microplastics. A) and B) Microbeads from personal care products; C) Secondary microplastics from degradation of larger plastic items; D) Secondary microplastics (microfibers) from synthetic fabrics. Image reproduced from Ref 7.

3. Public and Scientific Concern

Microplastics have been identified in every environmental compartment, including ocean water, fresh water, soils, groundwater, fresh water, sewage sludge, wastewater effluent, drinking water, and even air. As a result, there is a growing body of evidence indicating their occurrence all up and down the aquatic food chain. Microplastics have been found in benthic organisms, fish, birds, turtles, and whales, to name a few. Humans may be exposed through consumption of affected fish or shellfish, other contaminated food items such as honey and beer drinking water, or even drinking water.

Although plastics are generally considered chemically inert, there is some evidence that toxicity can occur at high enough concentrations. This may occur simply due to internal gastrointestinal blockage or tissue...
abrasion, although other routes are cited. An oft-cited concern is the ability of plastic particles to adsorb and slowly release other molecules with toxicological relevance, such as persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), endocrine disruptors and carcinogens. Additionally, plastic additives such as UV sensitizers, flame retardants, and phthalates may be released from the particles themselves as they degrade. This “sponge” effect may be especially pronounced for smaller microplastics (such as nanoplastics), where the surface-area-to-volume ratio is highest, and the particles have the ability to penetrate membranes and affect internal cell function.

However the question of whether toxicity occurs at the concentrations found in the environment is still under debate. Studies citing adverse biological impacts of microplastics typically occur in a laboratory setting, where organisms are intentionally exposed to large doses. To better understand actual risk, some researchers are calling for a systematic risk analysis framework that account for realistic exposure scenarios and known adverse effects.

4. Microplastics from PET carpet?

No studies were found in this effort that investigated microplastic release from PET carpet fibers. However, we can infer from previous work that PET itself can degrade, and that secondary microplastics can result from degraded PET. By inference, the introduction of secondary microplastics is possible.

GHD’s Final Feasibility Report submitted to CARE in March 2017 included two appendices (Appendix A and Appendix D) which discussed the potential for PET carpet fibers to degrade due to chemical or biological processes, under what general conditions this could happen, and what contaminants could result. The findings are briefly summarized below, with a focus on mechanisms relevant for aqueous environments.

PET can hydrolyze (be broken down by water) at high or low pH, with rates that increase as the pH moves away from 7. Hydrolysis rates also increase with temperature. Photodegradation can cause embrittlement of PET, although sunlight exposure is unlikely given the feasible applications. As of 2015, one literature example existed for microbiological degradation of PET, and this bacteria was found only in a landfill. In addition to chemical and biological degradation, mechanical work can also cause erosion of PET fibers. This could be induced by friction or even continuous flow of water. It is further expected that PET carpet fiber (made predominantly from recycled plastic bottles) would be more sensitive to degradation, since it has a higher surface area than bottle plastic and has already been partially degraded during recycling.

Of note are two recent reports indicating the presence of PET microplastics in a large percentage of tested bottled water samples. This is relevant because it was asserted that the bottle manufacturing process was the likely source of the contamination. Aside from PET, other plastics used in bottle manufacturing were also found in the water. The particles observed in both studies were predominantly small (< 100 µm). This suggests the possibility for secondary microplastics to be introduced during the bottle recycling process whereby PET fibers are made, although no data was found to confirm this.

It is therefore considered a possibility that secondary PET microplastics could be introduced to groundwater and soil, resulting from either degradation of PET fibers, or by microplastics that were generated during earlier manufacturing processes. However, the likelihood of this occurrence cannot be commented on.
5. **Behavior of Microplastics in Contact with Groundwater and Septic Systems**

If PET microplastics are introduced to groundwater, their subsequent fate is of interest. Although most transport research focuses on marine ecosystems, there are some reports concerning mobility in groundwater soil environments.

Physical characteristics such as the size, hydrophobicity (water solubility), density, surface charge, and are all expected to be determining factors that influence how particles move in an aqueous subsurface environment. Shape is of particular interest, as fibers would more likely become entangled in the soil and are expected to interact with soil biota differently. Microplastics of any shape may be embedded within soil aggregates, providing the potential for immobilization. Aside from these insights, however, relatively little is known about fate or potential distribution within the foodweb.

Microplastics in septic system leach fields may come in contact with solid human waste. Wastewater treatment studies indicate that microplastics removed in treatment are partially retained in the activated sludge stage, meaning this sludge may serve as an adsorption compartment for microplastics.

6. **CA Regulation**

A search of the California Water Resources Control Board (Water Board) website revealed no information page on microplastics. Microplastics are sometimes grouped under the umbrella of "emerging contaminants" by environmental NGOs and government agencies, but a review of the Water Board’s efforts regarding monitoring of emerging contaminants makes no mention of microplastics.

Two proposed bills, both introduced in February 2018, may provide some insight into the state’s concern with microplastics. Senate Bill SB 1422 would require the State Water Resources Control Board to begin monitoring and publicly reporting the levels of microplastics in drinking water. Assembly Bill AB 2379 would require all providers of fabric composed of more than 50% synthetic material to carry a label which states the possibility of the material to shed plastic microfibers when washed. If passed, the requirements of this bill would be effective in January 2020. These two bills represent examples of a regulatory approach to contamination reduction: Occurrence monitoring and source control, respectively. A third paradigm, the passing of effluent limitations, generally follows occurrence monitoring. This research did not find any proposed regulation or directives that would lead to effluent limitations on microplastics under California law in the near future.

The only federal regulation found regarding microplastics is a source-control effort. The Microbead-Free Waters Act of 2015 prohibits the use of microbeads (a primary microplastic) in over-the-counter rinse-off

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*www.waterboards.ca.gov*

† See the following:
- [https://www.waterboards.ca.gov/water_issues/programs/swamp/cec_aquatic/](https://www.waterboards.ca.gov/water_issues/programs/swamp/cec_aquatic/)
cosmetic products. The final deadline to stop the delivery of these products in to interstate commerce is July 2019.

The most restrictive regulation found globally is in Canada, where microplastics have been added to the to that country's list of toxic compounds, under the Canadian Environmental Protection Act.\(^5\)

7. **Measurement of Microplastics**

The measurement of particles at these sizes with sufficient throughput is notoriously difficult. There is an agreed-upon lack of standardization of sampling plans and analytical methodologies for the measurement of microplastic concentration in environmental media.\(^2,4,5\) While visual inspection may be useful for larger particles, the issue becomes more complicated as particles decrease in size. Consequently the analytical methods employed are highly dependent on the size of the particles in question. Quality control measures are considered particularly important when measuring microplastics, for the reasons cited above and due to the potential for contamination.\(^8\) Although not discussed here, it is important also to consider sampling techniques, which are likewise not standardized. Microplastics tend to distribute themselves non-uniformly in media, making it difficult to collect representative samples and achieve accuracy in measurement. Additionally, the potential for contamination is high, due to the ubiquity of plastics. Therefore standardized sampling procedures are being developed, but are not yet widely adopted.\(^2\)

A recent review by Renner *et al* compares different conventional and emerging analytical techniques to measure the occurrence and concentration of microplastics in environmental media, and the information from this article is summarized below.\(^4\)

**7.1 Visual examination**

Visual examination is used in the majority of studies that cite environmental microplastics occurrence. Samples are imaged using the naked eye, optical microscopes or electron microscopes, depending on the size, and is suitable down to 500 \(\mu\)m. This technique is somewhat controversial, as it often does not rely on chemical or spectroscopic identification of plastics. There do exist protocols to avoid misidentification, but a reference to these protocols is often left out of reports.\(^4\)

**7.2 FTIR and Raman Spectroscopy**

Fourier-transform infrared (FTIR) and Raman spectroscopic imaging are emerging analytical techniques for microplastics, and many studies have used this technique. FTIR and Raman both require illumination of a sample with a focused laser of a chosen wavelength, which reveals chemical-specific information about the sample. These techniques prevent misidentification, as chemical signatures of a sample can be compared to standards or libraries of spectral data. Additionally, different types of plastics can be distinguished using this technique; e.g., PET, PE, and nylon would all have different spectral profiles when imaged this way. FTIR allows identification of plastics as small as 50 \(\mu\)m, and Raman reaches below 20 \(\mu\)m. However, some concern has been raised about the ability for Raman lasers to damage or alter particles.
7.3 Fluorescence and staining

Samples can also be stained with Nile Red dye and imaged using fluorescence. Nile Red fluoresces brightly when irradiated with blue light, and has been shown to preferentially adsorb to microplastics over debris or biological matter. Samples are pre-processed using density separation, where the microplastics float while denser objects settle. This technique can image particles down to “a few micrometers”, and can accurately distinguish plastic material from other debris. Unlike Raman and FTIR chemical signatures are not available for definitive chemical identification, however, fluorescence brightness can be used to distinguish different plastics by their hydrophobicity (their solubility in water).

7.4 GC/MS

Gas chromatography coupled with mass spectrometry (GC/MS) is a proven and reliable method for the identification of volatile and semi-volatile organic compounds. Although plastics have no volatility, GC/MS can be attached to a pyrolysis or thermal extraction and desorption (TED) device to oligomerize or otherwise increase the plastics’ volatility. While this technique permits chemical identification, there is some risk of misinterpretation, and matrix effects may be significant. There is no size limit for detection of particles using GC/MS, but measurement of particle sizes and particle numbers is not possible. Results are reported as mass concentrations.

8. Treatment

If microplastics are identified in a medium, the next question is how to remove them. Most research to-date has focused on removal of microplastics from municipal wastewater, and much less attention has been paid to technologies that could be employed on a smaller scale.

It is known that microplastics at least partially survive secondary municipal wastewater treatment, however tertiary treatment (likely due to the skimming and settling treatment steps) appears to be more effective. Additionally, recent research indicates that the addition of final-stage treatment steps can drastically improve wastewater treatment plant performance. These final-stage technologies include membrane bioreactor (MBR), rapid sand filtration, dissolved air flotation, and disc filters. Each of these was reported to increase microplastics removal to 40 to 99.9% by number, with the most effective being MBR. Electrocoagulation has been demonstrated as an effective removal option for microbeads, specifically, with an optimum performance of 99.24%.

For smaller-scale operations, any size-based separation technology is likely to be effective. Nanofiltration, ultrafiltration, reverse osmosis, and even conventional filtration using filters with small average pore sizes could be considered. However, these technologies can severely reduce flow rates, so to determine an appropriate treatment process it is important to understand the expected particle concentration, expected flow rates of contaminated water, and environmental factors.
9. Recommendations

This literature review highlights, among other things, uncertainty surrounding the toxicity of microplastics at environmentally relevant concentrations, poor understanding of the fate of microplastics in groundwater environments, and a lack of standardization in both sampling and measurement of this contaminant. It is therefore the opinion of the author that microplastics are not likely to be regulated under California law in the near future in such a way as to preclude the use of PET carpet fiber as filler for stormwater infiltration galleries or septic system leach pits.

If, however, the Water Board suggests or requires that a pilot study include some quantitative understanding of the ability for PET carpet fiber to introduce microplastic particles or fibers, there would seem to be two options:

- A deeper literature review that uncovers research not found in this study; or
- Implementation of a microplastics research study, either as a stand-alone laboratory testing effort, or as a part of the larger pilot tests.

If the second option is chosen, this research provides some guidance on where to begin. Firstly, given the often-cited “ubiquity” of these materials, it is important to understand background levels of microplastics in the environmental medium of interest, and the potential for contamination by sampling equipment or air. The choice of analytical method would likewise be very relevant, as they each have their own benefits and limitations. The Nile Red staining method with fluorescence imaging seems to be reasonably high-throughput, but does not allow definitive chemical identification. Proving that any microplastics are or are not PET would be critical, so using μ-FTIR or μ-Raman in a confirmatory or stand-alone capacity would add significant experimental value. It is suggested that any research study factor in the extremes of environmental conditions that the PET carpet could encounter, including temperature, pH, organics, high flow rates (potential to induce mechanical damage), and that microplastic degradation be quantified in terms of both concentration (by count or mass) and particle size distribution. Other considerations include the potential for adhesion to soils or sewage sludge.

In the eventuality that treatment were required, this would merit a separate, thorough analysis. GHD has an expansive network of water treatment design engineers and scientists, who specialize in targeting specific contaminants. Although microplastics are somewhat new as a contaminant, there would be adequate support to devise an optimal microplastics removal solution.

10. References

3. Thompson, Richard C; Olsen, Ylva; Mitchell, Richard P; Davis, Anthony; Rowland, Steven J; John, Anthony W G; Mcgonigle, Daniel; Russell, A. E. Lost at sea: where is all the plastic? *Science* (80-. ).


Appendix E – Degradation Proposal
Proposal for Professional Services:

Enzymatic Degradation of Polyethylene Terephthalate (PET) Carpet Fibers for Industrial Scale Recycling and Recovery – Phase 1

Carpet America Recovery Effort (CARE)

June 4, 2018
June 4, 2018

Bob Peoples
Executive Director
Carpet America Recovery Effort (CARE)

RE: Enzymatic Degradation of Polyethylene Terephthalate (PET) Carpet Fibers for Industrial Scale Recycling and Recovery – Phase 1

Dear Dr. Peoples:

On behalf of GHD, Joaquin Wright and Joyce Cheung are pleased to provide you with our proposal for professional services to assess the Enzymatic Degradation of Polyethylene Terephthalate (PET) Carpet Fibers for Industrial Scale Recycling and Recovery – Phase 1 (Project). Scientists have recently discovered an enzyme from a bacteria that can be harnessed to degrade PET plastics. Based on our understanding of the research performed to-date and discussions with research experts from the National Renewable Energy Laboratory (NREL), University of Southern Florida, and the University of Portsmouth in the UK, we believe that this project has significant potential to not only divert PET carpet from landfills, but also create a viable market for the recycling and recovery of PET carpet.

GHD understands the carpet recycling goals set forth by California law AB 2398 and administered by Carpet America Recovery Effort (CARE). GHD is currently working with CARE on several feasibility and pilot studies focused on utilizing the mechanical separation and physical properties of PET carpet for civil engineering applications. This project, however, will offer another recycling pathway and will focus on the chemical recycling of PET carpet, in which enzymes from bacteria will be utilized to break down PET to its building blocks.

As discussed in our proposal, our team was thoughtfully selected based on our recent and relevant experience on similar projects and other similar clients. For this project, we are teaming with the lead authors from the research team—NREL’s Gregg Beckham, University of Portsmouth’s John McGeehan, and Lee Woodcock from the University of South Florida.

We have identified a 3-phase project that can potentially divert post-consumer PET carpet in landfills through chemical recycling:

- Phase 1: Perform laboratory studies to extract enzymes, develop an efficient process to convert PET into its building blocks, and bio-engineer enzymes for commercialization.
- Phase 2: Implement industrial scale pilot study to facilitate PET carpet recycling and recovery.
- Phase 3: Develop model for promotion of independent businesses to recycle PET carpet and divert PET carpet from landfills.

This proposal focuses on the first phase of the project and discusses the specific issues, opportunities and constraints of this phase. This proposal also showcases our understanding, approach and team that will make this project a success.

Phase 1 is anticipated to be completed in a 1-year period. Phase 2 is anticipated to be performed within 3 years, and Phase 3 will be initiated after successful completion of Phases 1 and 2.

Our project approach and detailed scope of services in this proposal was developed to provide CARE with the high quality professional services it has come to expect on projects from GHD. We are excited about this project, and the opportunity to continue developing recycling pathways for PET carpet with you and your team.
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1. Project Need

1.1 Background

Polyethylene terephthalate (PET) carpet fiber is manufactured from recycled soda and water bottles that were originally formed from pellets of PET resin. Because PET carpet is not readily or commercially recyclable, the carpet is oftentimes transferred to landfills after it has served its useful life.

In 2016, scientists have discovered a new enzyme derived from bacteria that can degrade PET plastics. In April 2018, scientists and engineers inadvertently developed a more efficient enzyme that can degrade PET more effectively; this research was published in the Proceedings of the National Academy of Sciences (PNAS). During the enzymatic degradation of PET, PET is broken down into its building blocks, ethylene glycol and terephthalic acid, which are environmentally benign. This discovery can potentially lead to a recycling solution for millions of tons of plastic bottles or post-consumer carpet, made of PET, which could otherwise remain in the environment for hundreds of years.

While the research has produced a viable way to chemically degrade PET to its raw materials, an efficient and cost-effective way to apply this technology to PET carpet fiber at an industrial scale has not yet been developed.

1.2 Goals and Objectives

GHD’s team includes the lead researchers associated with analyzing the enzymatic degradation of PET carpet fibers for industrial scale recycling and recovery. The goal is to provide Carpet America Recovery Effort (CARE) with an alternative to placing PET fibers from post-consumer carpet (PCC) in landfills. Based on recent research, timely investment from CARE will allow us to take advantage of the industrial expertise and be at the forefront of utilizing enzymes to degrade PET to its building blocks. This would put CARE at the forefront of research and technology that will change the landscape of PET recycling. This technology has the potential to sustainably recycle all PET carpet.

GHD understands the carpet recycling goals set forth by California law AB 2398 and administered by CARE. GHD is currently working with CARE on several feasibility and pilot studies focused on utilizing the mechanical separation and physical properties of PET carpet for civil engineering applications. This project, however, will offer another recycling pathway and will focus on the chemical recycling of PET carpet, in which enzymes from bacteria will be utilized to break down PET to its building blocks.

We have identified a 3-phase project that can potentially divert post-consumer PET carpet in landfills through chemical recycling, as shown in Figure 1 on the next page.

This proposal focuses on the first phase of the project and discusses the specific issues, opportunities and constraints of this phase. The project approach and scope of work for Phases 2 and 3 will be developed after completion of Phase 1.

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Phase 1 is anticipated to be completed in a 1-year period. Phase 2 is anticipated to be performed within 3 years, and Phase 3 will be initiated after successful completion of Phases 1 and 2.

![Figure 1: Phases to develop enzymatic degradation of PET carpet fibers for industrial scale recycling and recovery](image)

### 2. Team Qualifications & Experience

#### 2.1 Firm Overview

GHD is one of the world’s leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, architecture, environmental and construction services to private and public sector clients.

Established in 1928 and privately owned by our people, GHD operates across five continents – Asia, Australia, Europe, North and South America – and the Pacific region. We employ more than 8,500 people in over 200 offices to deliver projects with high standards of safety, quality and ethics across the entire asset value chain. Driven by a client-service led culture, we connect the knowledge, skill and experience of our people with innovative practices, technical capabilities and robust systems to create lasting community benefits.

GHD Inc. is registered with the California Department of Industrial Relations: #1000018754.

#### 2.2 Project Team

GHD brings extensive, relevant project experience to assess the Enzymatic Degradation of PET Carpet Fibers for Industrial Scale Recycling and Recovery. The selected project team has a strong background in research and development of new products. Specifically, GHD has performed an initial feasibility study to understand the material properties and chemical constituents of PET carpet fiber for use in civil engineering applications. GHD is also currently implementing pilot studies with Humboldt State University on the feasibility of utilizing PET carpet for septic system leach fields or storm water infiltration galleries.
Additionally, GHD is a current consultant to the California Department of Resources Recycling and Recovery (CalRecycle), and we have reliably and continuously delivered a variety of services over the past five years, including:

- Identification and investigation of potential barriers and environmental impacts to using tire derived aggregate (TDA);
- Technical assistance for TDA pilot demonstration and grant projects; and
- Research investigations for new civil engineering applications for TDA.

GHD’s experience on the product testing and research and development of tire derived aggregate (TDA) can be translated laterally to assess whether PET carpet fibers can be successfully recycled and recovered through enzymatic degradation. Relevant project experience is provided in detail in Appendix B.

For this project, we are teaming with the lead authors from the research team that published the journal article in PNAS in April 2018:

- Gregg Beckham - National Renewable Energy Laboratory (NREL)
- John McGeehan - University of Portsmouth in UK
- Lee Woodcock - University of South Florida

This project will also engage Moving Images to document the Phase 1 research process. The documentation will be used to develop a short video that highlights CARE’s efforts to develop PET recycling pathways.

Joaquin Wright will be the Project Manager and will be the main point of contact for CARE. His responsibilities will include schedule and budget control, overall project management, and outreach and education of CARE’s sustainability efforts. The project member organization chart is provided in Figure 2. A brief description of each project team member is provided on the next page and resumes are included in Appendix C.

**Figure 2: Project Team Member Organization Chart**
Joaquin Wright **Senior Project Manager**  
*Humboldt State University (HSU), Environmental Resource Engineering, 2000.*  

Joaquin has over 16 years of experience in the Environmental Engineering field, including extensive environmental remediation, landfill design, regulatory compliance, and construction management experience. He is an Adjunct Professor at HSU teaching Solid Waste Management. He is also an expert in Tire Derived Aggregate (TDA) use, and is extensively involved with TDA research and education in civil engineering applications through the support of the California Department of Resources and Recovery (CalRecycle). Joaquin is also the project manager for the feasibility and pilot studies of utilizing PET carpet in civil engineering applications.

Alex Culick, PE **Project Principal**  
*B.S. Environmental Resources Engineering, Humboldt State University, Arcata, CA, 1987*  

Alex is a Managing Principal with GHD with over 20 years of experience specializing in, infrastructure development projects and construction management and project implementation oversight. Currently Alex has been providing senior level and technical quality assurance and project reviews during design phase and prior to bidding and implementation.

Joyce Cheung, PE **Civil Engineer**  
*M.Eng. Civil and Environmental Engineering, MIT, 2014; B.S. Engineering Science, Smith College, 2009*  

Joyce has over 8 years of extensive inter-discipline experience working in the water and wastewater industry, with projects that include design and construction administration of water treatment, collection systems, wastewater treatment facilities, stormwater management solutions and pump stations. Joyce was also involved with the cost-benefit assessment of Tire Derived Aggregate (TDA) as a lightweight fill material in civil engineering applications. She conducted field studies to determine the density of TDA in light-rail vibration mitigation applications and bioretention systems, and also analyzed the settlement of TDA in road embankment applications, where she developed a settlement curve to aid engineers in the design of TDA embankments. Joyce is also the project engineer for the feasibility study of utilizing PET carpet in civil engineering applications.
**Jenna Rais** Biologist  
*M.S. Environmental Management, University of San Francisco, expected 2019;  
B.A Integrative Biology, University of California, Berkeley, 2005*

Jenna has environmental consulting experience that includes natural and biological resources work such as biological monitoring for special status species during construction activities; field surveying and reconnaissance site visits; wetland delineations; and, Geographic Information Systems mapping. She also has experience in research of aquatic insects and biological control.

**Gregg Beckham, PhD** Senior Research Fellow at the National Renewable Energy Laboratory  
*PhD, Chemical Engineering, MIT, 2007;  
M.S. Chemical Engineering Practice, MIT, 2004;  
B.S. Chemical Engineering, Oklahoma State University, 2002*

Gregg is a Senior Engineer at the National Renewable Energy Laboratory (NREL), where he leads and works with an interdisciplinary team of biologists, chemists, and engineers on conversion of biomass to fuels, chemicals, and materials including metabolic engineering, fermentation, separations, catalysis, biopolymer and carbon fiber production, and lignin and waste valorization.

**Lee Woodcock, PhD** Associate Professor at University of South Florida  
*Ph.D. Chemistry, University of Georgia, 2003;  
B.S. Chemistry, Appalachian State University, 1998*

Lee is an Associate Professor in the Department of Chemistry at the University of South Florida. Lee’s research focuses on developing and employing computational methodology to solve interesting problems that exist at the interface of biophysics, medicine, and materials.

**John McGeehan, PhD** Professor at University of Portsmouth, UK  
*Ph.D. Virology, Medical Research Council (MRC Virology Unit), Church Street, Glasgow, UK, 1996;  
B.Sc. Honours Microbiology, University of Glasgow, UK, 1993*

John is a Professor of Structural Biology and Director of the Institute of Biological & Biomedical Sciences at the University of Portsmouth in the UK. John’s research focuses on structure-led enzyme engineering, where he combines X-ray crystallography with other biophysical methods such as spectroscopy, analytical ultracentrifugation and small-angle X-ray and neutron scattering.
3. Project Understanding and Approach

PET carpet fibers are challenging to recover and recycle effectively. Mechanical approaches today can fractionate carpet into its fiber, non-PET polymer, and inorganic components, but the resulting PET in fiber form (commonly known as “fluff”) remains challenging to efficiently and cost effectively recycle back to carpet or bottle-grade PET. Chemical recycling strategies have been developed, but to-date they remain too expensive to efficiently and rapidly break down PET to building blocks, often requiring expensive chemical catalysts that are hard to recycle and/or high excess of solvents that are also challenging to fully recover. A chemical (or biological) recycling strategy that would be able to break down PET, either in whole carpet or in recovered PET fibers, to building blocks that is more cost effective than existing strategies is sorely needed and would represent a potential paradigm change for the industry.

While it has been known for more than two decades that naturally occurring enzymes are able to break down PET, these enzymes have not been not yet been deployed in a process context or compared systematically on PET fibers from carpet or bottles. Furthermore, recent enzyme discovery programs have yielded several exciting thermophilic variants of PET-degrading enzymes that can yield significant gains in terms of efficiency.

3.1 Project Approach

The first phase of this project will primarily focus on laboratory studies facilitated by Dr. Beckham, Dr. Woodcock and Dr. McGeehan to examine and enhance enzyme performance to degrade PET. This phase will be implemented over a 1-year period, and will include the following milestones:

**Milestone 1. Express and purify at least 25 thermophilic PET-degrading enzymes:**

The first component of the project will examine metagenomic databases in collaboration with existing partners to identify PET-degrading enzymes from thermophilic bacteria that should be able to operate above the glass transition temperature of PET (which would increase the surface area, and hence the rate of PET degradation). The research labs are setup to do this efficiently and rapidly, and we can work with industrial partners if scale-up of enzyme production is required as part of the project. To ensure success, this component of the project will be initiated with at least 75 new enzymes in case some do not successfully express or are inactive on PET.

**Milestone 2. Develop a process for enzymatic breakdown of PET fibers:**

Leveraging capabilities and previous experience in process design for biomass conversion, we will conduct enzymatic studies to convert PET into its building blocks, ethylene glycol and terephthalic acid using the enzymes expressed in Milestone 1. We will test both whole carpet and carpet fibers already provided by our industrial partners (e.g., Shaw Floors). The goal will be to test enzyme performance across a range of temperatures, pH values, buffers, and with differing loads of enzymes, normalized to the PET content. We will use agitated bioreactors at the small scale (e.g., in an existing BioLector Pro, which allows for 24 parallel experiments to be temperature and pH controlled) to mimic scaled-up industrial conditions. Substrate characterization will be conducted before and after each enzyme treatment to measure the substrate turnover, with a project stretch goal of achieving complete PET conversion in PET fluff or whole carpet of ≥80% in 7 days.
Milestone 3. Initiate engineering of thermophilic enzymes using computation and structural biology driven methods:

Using structural biology methods, directed evolution, and advanced computational approaches, we will initiate the development of improved variants of the optimal PET-degrading enzymes identified in Milestones 1 and 2. This is the highest-risk portion of the project, but is an important component to continue to obtain improved enzyme variants. This work will leverage key and complementary expertise at all three partner institutions.

3.2 Scope of Services

The following scope of work outlines the proposed steps for performing Phase 1 of this project.

Task 1 – Project Management

GHD will begin the project with a kickoff meeting with team members. The purpose of the meeting is to review the scope, budget and schedule.

Project management services during the project will include the following: internal progress meetings, four (4) progress meetings with CARE, one of which includes a site visit to observe the laboratory testing facilities. GHD will prepare monthly progress reports that detail progress on scope, schedule, and budget.

Task 1 Deliverables:

- Monthly Progress Reports with Invoices
- Progress Meeting summaries

Task 2 – Laboratory Testing

NREL, University of Portsmouth, and the University of Southern Florida will develop the laboratory studies to examine, test, and optimize enzyme performance to degrade PET. Details for this task are provided in the Project Approach under Section 3.1. This task is fundamental to provide the necessary information to mimic scaled-up conditions for industrial recycling and recovery of PET. A report of the test methods and results will be provided to GHD, which will be included as an appendix to the Summary Report that GHD will submit to CARE under Task 3.

Task 3 – Summary Reporting and Program Development

This task includes the analysis of the laboratory test results from NREL, University of Portsmouth, and the University of Southern Florida. GHD will summarize the findings in a draft Summary Report for CARE to review. GHD will revise the draft report based on feedback and written comments provided by CARE, and will then submit a final Summary Report, which will include discussions and recommendations. GHD will also provide a PowerPoint presentation of the Phase 1 study to CARE at the end of this project.

The Summary Report will include the following components:

1) Introduction describing the purpose and organization of the report and general background information, including the need to develop a market for PET.
2) Presentation and evaluation of the laboratory testing results.
3) Discussion and recommendations for Phase 2 of the project.
Task 3 Deliverables:
- Draft and Final Summary Report (electronic PDF and 3 hard copies)
- PowerPoint presentation of Pilot Study (electronic PowerPoint)

Task 4 – Video Documentation

This video will record the milestones associated with the initial laboratory testing performed on PET carpet and would include interviews with the research team. The video will focus on the potential of degrading PET down to its raw materials and discuss the implications that this research may have on the post-consumer carpet recycling industry. At the same time, we will show the commitment that CARE has towards finding safe and sustainable reuses for this problematic waste material.

This will be a 5-10 minute video that can be used for outreach and educational efforts. The video is anticipated to take approximately 10 days of shooting and 15 days of editing.

Task 4 Deliverables:
- 5-10 minute video in MPEG format
4. **Closing**

GHD is a global company, and a long-standing firm in California with a proven ability to deliver comprehensive engineering services. Our team includes local and global experts that are excited at the prospect of working with CARE to advance the goal of minimizing post-consumer PET carpet in landfills. GHD has a record of accomplishment in developing new products (e.g. tire derived aggregate for CalRecycle), and our approach matches your need for high quality and cost-effective services. If you have any questions regarding the proposal, our proposed approach, or our project team, please do not hesitate to contact us.
about GHD

GHD is one of the world’s leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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