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LABORATORY TREATABILITY REPORT

Gateway Intermodal Dock, Skagway, Alaska **Project:** 140159-04.01

This laboratory treatability report summarizes sediment treatability testing performed to support development of dredge material reuse options for the Gateway Intermodal Dock Redevelopment Reconstruction Project and Legacy Harbor Contaminant Mitigation Program in Skagway, Alaska.

NARRATIVE

Anchor QEA characterized subsurface sediment adjacent to the Skagway Ore Dock in January 2015 on behalf of the Municipality of Skagway. Leachability testing was also performed as part of the sediment characterization. Results of the leachability screening tests indicated a potential for the release of lead, copper, and select polycyclic aromatic hydrocarbons (PAHs) in leachate from the dredged material, dependent on sediment placement conditions[1]. The treatability testing was performed to address the potential release of lead, copper[2], and polycyclic aromatic hydrocarbons (PAHs) through leaching of untreated dredged material after material placement. Treatability testing was performed on a composite sediment sample using amendments and amendment mixtures consisting of bone meal, Portland cement, granular activated carbon, and ferrous sulfate. The amended sediment was subjected to leachability testing using freshwater and seawater solutions. Treatability testing was performed in accordance with the Alaska Department of Environmental Conservation (ADEC)-approved Work Plan[3]. Chemical analysis was performed by an ADEC-certified laboratory (TestAmerica-Seattle) and analytical data met ADEC data verification guidelines. Data quality summaries and data review checklists are provided with the analytical data reports as Appendices A through C.

[1] Anchor QEA, LLC, 2015a. Sediment Characterization Report. Skagway Ore Dock and Small Boat Harbor Dredging Gateway Intermodal Dock Reconstruction Project and Legacy Harbor Contaminant Mitigation Program. June 2015.

[2] Review of laboratory quality assurance sample results suggested that the detections of copper were likely due to matrix interference. This matrix interference was addressed by the analytical laboratory performing five times dilution of all metals samples for the treatability testing.

[3] Anchor QEA, 2015b. Gateway Dredge Material Treatability Study Work Plan. September 17, 2015.

METHOD NOTES

SAMPLE RECEIPT AND PREPARATION

Sediment samples collected adjacent to the Skagway Ore Dock were transferred to the Anchor QEA Environmental Geochemistry Laboratory (EGL) for treatability testing. Archived samples from the January 2015 sampling event were transferred from SGS Environmental Services in Anchorage, Alaska, to the EGL on October 23, 2015. Samples remained frozen during storage and transport, and were only thawed to allow homogenization of the composite sample, which was performed under a nitrogen atmosphere.

COMPOSITE SEDIMENT

The composite sediment used in the treatability testing included: SOD-01 (0 to 6.5 feet), SOD-02 (0 to 8.5 feet), SOD-03 (0 to 6.5 feet), and SOD-05 (0 to 3.5 feet). Duplicate samples of the composite sediment were submitted for analysis of total metals (lead, copper, antimony, barium, beryllium, cadmium, chromium, copper, mercury, nickel, selenium, silver, thallium, and zinc) and priority PAHs. The results are included as Attachment 1. The composite sediment had 5,608 micrograms per kilogram (µg/kg) total PAHs, 1,700 milligrams per kilogram (mg/kg) lead, and 2,900 mg/kg zinc, consistent with the concentrations reported previously for individual samples within the anticipated dredge prism.

SYNTHETIC PRECIPITATION LEACHING PROCEDURE

The Synthetic Precipitation Leaching Procedure (SPLP) was performed in accordance with the Work Plan and U.S. Environmental Protection Agency (USEPA) Method 1312[4]. SPLP was performed using the mildly acidic solution (pH = 5) required for sites west of the Mississippi River, at a liquid-to-solid ratio (L/S) of 20, with continuous agitation for 18 hours.

SEQUENTIAL BATCH LEACH TEST

The sequential batch leach test (SBLT) was performed in accordance with the EGL standard operating procedures and the Uplands Testing Manual[5], either with reagent water as the

[4] U.S. Environmental Protection Agency, 1994. Synthetic Precipitation Leaching Procedure. EPA Method 1312. Washington, DC.

[5] Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual. U.S. Army Corps of Engineers, January 2003 ERDC/EL TR-03-1.

leaching solution, or modified to use synthetic seawater as the leaching solution. Both the freshwater and seawater SBLT were performed at an L/S = 20. SBLT solutions were deoxygenated by nitrogen purging prior to each leaching solution exchange.

RESULTS: BONE MEAL SCREENING RESULTS

Three types of bone meal were tested, in sediment mixtures, for lead leachability. Sediment was mixed with crushed bone meal, prilled bone meal, or fish bone meal at an application rate of 2% bone meal by weight, and allowed to cure for 3 days. The treated and cured sediments were subjected to SPLP (in duplicate) and leachate samples submitted for dissolved lead analysis. Analytical data is provided in Attachment 2. The lead concentration in SPLP leachates was similar for all three bone meal amendments as summarized in Table 1.

Table 1
Bone Meal Screening Test Results

Mixture	Average SPLP Lead (µg/L)	Estimated Price ($/Ton)
2% Alaska Sea-Ag Fish	17.8	$925
2% Bridgewell Prilled	19.5	$920
2% Bridgewell Crushed	16.3	$895

Notes:
The estimated price does not include delivery.
µg/L = microgram per liter
SPLP = Synthetic Precipitation Leaching Procedure

Given the similarity in cost and performance, the local supplier, Alaska Sea-Ag, was selected for use in subsequent treatability testing.

In addition to the SPLP, the toxicity characteristic leaching procedure (TCLP[6]) was also performed for sediment amended with 2% fish bone meal (Attachment 3).

RESULTS: AMENDMENT MIXTURE SCREENING TESTS

After selection of a bone meal type (Alaska Sea-Ag), testing of amendment was conducted. The following amendments were included in the amendment mixture screening tests:

[6] U.S. Environmental Protection Agency, 2011. Toxicity Characteristic Leaching Procedure. EPA Method 1311. Washington, DC.

- Three bone meal application rates were tested: 2%, 5%, and 10% by weight
- Portland cement was tested at 2% (pH neutralization) and 5% (solidification/stabilization)
- Ferrous sulfate was tested in combination with bone meal and Portland cement (to offset cement alkalinity and increase the adsorption capacity)
- Granular activated carbon was tested in combination with bone meal and cement (PAH adsorption).

The treated sediments were cured for 1 week and then subjected to SPLP testing with chemical analysis of the leachate for dissolved lead, copper, and PAHs. Laboratory analytical results are provided in Attachment 4.

Based on the initial results of the amendment, two additional amendment mixtures were tested. The mixture of 10% bone meal, 3% ferrous sulfate, and 2% Portland cement was the most effective amendment mixture in the original testing. However, the results for the bone meal only amendment determined that the lower amendment rates were more effective, so it was expected a lower percent bone meal addition would also be effective in the mixture with ferrous sulfate and Portland cement, reducing overall amendment costs. The additional test mixtures were prepared with either 2% or 5% bone meal combined with 3% ferrous sulfate and 2% Portland cement. These mixtures were allowed to cure for one week and subjected to SPLP. The amendment mixture screening results are summarized in Table 2.

Bone meal amendment did not have a noticeable impact on sediment texture. Amendment mixtures with 2% Portland cement were very similar to the untreated sediment (excess water, not cohesive). Amendment mixtures with 5% Portland cement "clumped" to generate a granular material. None of the amendment mixtures formed a hardened solid because the Portland cement addition was generally low compared to initial moisture content.

The SPLP leachates for the different treatments had a range of lead concentrations, although several treatments sequestered lead such that minimal (or no) dilution would be required to meet relevant criteria. Copper was below the detection limit for all mixtures with the exception of those containing 5% Portland cement. PAH concentrations were very low in the leachates, with sum PAHs typically less than 1 microgram per liter (µg/L).

Table 2
Amendment Mixture Test Results

Mixture	SPLP Lead (µg/L)	SPLP Copper (µg/L)	∑PAHs (µg/L)
2% Bone Meal	87	3 U	0.32
5% Bone Meal	59	3 U	0.60
10% Bone Meal	470	3 U	0.59
5% Bone Meal + 2% GAC	47	3 U	1.6
2% Bone Meal + 2% Cement	27	3 U	0.11
5% Bone Meal + 2% Cement	92	3 U	0.76
10% Bone Meal + 2% Cement	200	3 U	0.42
5% Bone Meal + 2% Cement + 2% GAC	79	3 U	0.16
10% Bone Meal + 3% $FeSO_4$ + 2% Cement	10	3 U	0.11
5% Bone Meal + 5% GAC	230	3 U	0.11
2% Bone Meal + 5% Cement	39	15	0.11
5% Bone Meal + 5% Cement	42	77	0.11
10% Bone Meal + 5% Cement	130	130	0.16
5% Bone Meal + 5% Cement + 5% GAC	20	96	0.11
5% Bone Meal + 3% $FeSO_4$ + 2% Cement	2.1	3 U	0.21
2% Bone Meal + 3% $FeSO_4$ + 2% Cement	12	3 U	0.38

Notes:
∑PAHs = sum of priority polycyclic aromatic hydrocarbons (PAHs), with non-detects at 1/2 the method detection limit (MDL).
µg/L = microgram per liter
$FeSO_4$ = ferrous sulfate
GAC = granular activated carbon
SPLP = Synthetic Precipitation Leaching Procedure
U = analyte not detected (MDL is shown)

SCREENING TEST OBSERVATIONS

- For bone meal alone, the lower amendment rates (2% and 5%) were more effective than the 10% amendment rate, potentially due to the elevated pH observed at the 10% amendment rate.
- For a given rate of bone meal amendment, the addition of 2% Portland cement improved the amendment performance as compared to bone meal alone.
- The most effective amendment mixture in reducing contaminant leachability consisted of 3% ferrous sulfate, 5% bone meal, and 2% Portland cement, with an

SPLP lead concentration of 2.1 µg/L, copper below the detection limit, and sum PAHs less than 0.5 µg/L.

RESULTS: AMENDMENT MIXTURE PERFORMANCE CONFIRMATION TESTING

To confirm the applicability of the treatment that performed in the SPLP testing, the selected mixture was subjected to SBLT. The selected amendment mixture was 5% bone meal, 3% ferrous sulfate, and 2% Portland cement. The treated sediment was cured for 1 week and subjected to both seawater and freshwater SBLT to evaluate long-term treatment performance under simulated placement in marine and freshwater environments. SBLT leachates were analyzed for PAHs and dissolved lead, copper, antimony, barium, beryllium, cadmium, chromium, copper, mercury, nickel, selenium, silver, thallium, and zinc. Analytical results are provided in Attachments 5 and 6.

SEAWATER

The seawater SBLT leachates had lead concentrations less than the method reporting limit (MRL) and copper concentrations less than the method detection limit. There were no exceedances of Alaska's marine chronic aquatic life criteria[7] for lead, copper, arsenic, cadmium, mercury, selenium, silver, zinc, or total aromatic hydrocarbons. The first batch leachate exceeded the chronic criteria for nickel; however, it did not exceed the acute criteria and was less than the MRL in subsequent batches. The SBLT results for seawater are summarized in Table 3.

[7] Alaska Department of Environmental Conservation, 2008. Alaska Water Quality Manual.

Table 3
Seawater SBLT Results

		Acute Criteria	Chronic Criteria	Seawater SBLT Average
Dissolved Metals (µg/L)	Lead	210	8.1	0.41
	Copper	4.8	3.1	3.0 U
	Arsenic	69	36	8.3
	Cadmium	40	8.8	0.14 U
	Mercury	1.8	0.94	0.041 U
	Nickel	74	8.2	18 J
	Selenium	290	71	5.3 B
	Silver	1.9		0.15 U
	Zinc	90	81	13.6
∑PAHs (µg/L)			10	2.6

Notes:
Alaska Department of Environmental Conservation (ADEC) Marine Aquatic Life Criteria (ADEC 2008)
∑PAHs = sum of the 16 priority PAHs, non-detects included at the most elevated reporting limit.
µg/L = microgram per liter
B = compound was found in the blank and samples
J = estimated value
SBLT = sequential batch leach test
U = analyte not detected (method detection limit is shown)

FRESHWATER

The freshwater SBLT results were compared to drinking water criteria to evaluate potential impacts from water in contact with treated sediment (i.e., leachate) mixing with groundwater that may ultimately be used as a drinking water source. The first batch leachate exceeded the drinking water criteria for antimony and arsenic; however, both were below the criteria in subsequent batches. All but the first batch of leachates had lead exceedances; however, this exceedance is for water in direct contact with the material and does not account for dilution-attenuation. There were no other drinking water exceedances. The freshwater SBLT results were also compared to the aquatic life criteria to evaluate potential mixing of leachate runoff with potential adjacent surface water bodies. The SBLT results for freshwater are summarized in Table 4.

Table 4
Freshwater SBLT Results

	Constituent	Acute	Chronic	Drinking Water Criteria	SBLT Leachate (average)
Dissolved Metals (µg/L)	Antimony			6	4.5
	Arsenic	340	150	10	8.1
	Barium	--	--	2,000	45.8
	Beryllium	--	--	4	0.51 U
	Cadmium	2	0.25	5	0.14 U
	Chromium	570	74	100	1.11
	Copper	13.4	8.96	1,300	3.0 U
	Iron	--	1,000	--	1,120
	Lead	64.6	2.52	15	105
	Mercury	1.4	0.77	2	0.041 U
	Nickel	470	52	--	3.85 J
	Selenium	24	5	50	1.7 J
	Silver	3.22	--	--	0.15 U
	Thallium	--	--	2	0.71 U
	Zinc	117	118	--	19.4 J
∑PAHs (µg/L)			10	--	3.3
Benzo[a]pyrene (µg/L)			--	0.2	0.1 U

Notes:
Alaska Department of Environmental Conservation (ADEC) drinking water criteria is equivalent to the federal maximum contaminant level (MCL, except for copper and lead [federal MCL]).
Arsenic, benzo(a)pyrene, and lead have federal MCL goals (MCLG) of zero.
Secondary drinking water standards (federal): copper (1,000 µg/L), iron (300 µg/L), silver (100 µg/L), and zinc (5,000 µg/L).
Metals criteria as listed in ADEC (2008).
Total aqueous aromatic hydrocarbons as indicated in ADEC (2012).
ADEC freshwater criteria for cadmium, chromium, copper, lead, nickel, silver, and zinc calculated for water hardness of 100 parts per million (ppm).
Standards are for chromium (III).
µg/L = microgram per liter
J = estimated value
SBLT = sequential batch leach test
U = analyte not detected (method detection limit is shown)

DILUTION-ATTENUATION EVALUATION

A dilution-attenuation factor (DAF) is typically applied to leachate results to account for real-world conditions. This screening factor, based on USEPA guidance, typically ranges from 10 to 20. Per ADEC comments on the Work Plan, a site-specific dilution factor should be applied to the leachate results presented in this report. As the placement location for the

material tested in this report is not currently identified, it is not possible to apply site-specific mixing zone and dilution evaluation at this time due to the lack of information regarding potential reuse scenarios. It is recommended that a site-specific DAF be developed once a placement location has been determined.

RECOMMENDATIONS

Amendment of dredged sediment with 5% bone meal, 3% ferrous sulfate, and 2% Portland cement would be appropriate for beneficial reuse in a marine setting. Additionally, this amendment mixture is expected to be appropriate for uplands reuse of amended sediment, pending development of site-specific DAF as placement scenarios are considered.

It should be noted that treatability testing was performed on a composite sample that is representative of contaminant concentration levels of anticipated dredge material in the dredge prism based on the currently available samples. The performance of the amendment mixture was assessed without a direct consideration of high concentration "hot-spots" but completed on anticipated average contaminant concentrations in the dredge prism. However, there is additional conservatism built into the treatability testing program that would likely account for localized areas of higher concentration sediments that may be present within the dredge prisms. Conservatism built into the treatability testing program includes the following:

- Treatability testing indicated that a lower bone meal concentration would likely be effective for the anticipated concentrations; therefore, some additional leeway for stabilizing the elevated concentrations is expected.
- Actual treated material during construction would also include the low-metals concentration coarse fraction (i.e., gravels) that were excluded from the treatability testing. This would functionally increase the total volume by approximately 30% with uncontaminated coarse materials in the actual site dredge material.
- Dredging will include an overdredge allowance that will allow and incentivize the contractor to also dredge "clean" material below the footprint of the dredge prism. This material will be mixed with the higher areas of contamination during the dredging and handling operations, functionally diluting potential areas of higher concentrations prior to the addition of treatment during construction.