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December 6, 2016

Mr. William Beck
Senior Environmental Project Manager
Stericycle Environmental Solutions
18000 72nd Avenue South, Suite 217
Kent, WA 98032

Re: **PSC-Georgetown Facility**
1,4-dioxane Remedial Design/Remedial Action
Technical Memorandum: ISB Phase I and ISCO Phase II Results and Downgradient Area Pilot Study Work Plan
Ecology/EPA ID#: WAD 00081 2909

Dear Mr. Beck:

On November 17, 2016, the Washington State Department of Ecology (Ecology) received the *Technical Memorandum: ISB Phase I and ISCO Phase II Results and Downgradient Area Pilot Study Work Plan* (November 17 Pilot Study Work Plan) for Stericycle Environmental Solutions' PSC-Georgetown site. The November 17 Pilot Study Work Plan is a required deliverable of Agreed Order DE 7347 and its Cleanup Action Plan (CAP), amended in August 2015. Thank you for submitting the document in accordance with the established due date.

The November 17 Pilot Study Work Plan includes monitoring information gathered by Stericycle during the June through August Maynard Ave. ISCO pilot study (in Section 3), and during bench-scale bioremediation studies (in Section 2). Sections 4 and 5 of the document also propose new field studies using both technologies (in different areas of 1,4-dioxane groundwater contamination). Conclusions reached from last summer's ISCO pilot study and the bench-scale bioremediation studies include:

- Declines in 1,4-dioxane concentrations in the ISCO pilot study area occurred later and were more modest than expected. Dioxane levels measured at well 122-60, though more than 20% lower in September than in June (pre-injection), actually increased by about 14% three weeks following oxidant injections. Similar behavior was observed at well IMW-1, where concentrations decreased more than 20% between June (pre-injection) and late September, but increased to levels above baseline in later June, July, and August. Among the study's four monitoring wells, reductions in dioxane were highest at IMW-2.

But significant reductions were not observed at this location – about five feet NW of the most northern injection point – until at least six weeks after injections.

- 1,4-dioxane concentrations measured via direct push sampling varied in ways that were difficult to interpret. Concentrations detected one week after injections (at DP-1 and DP-2) were elevated. Levels measured a week later (at DP-3 and DP-4, very close to DP-1 and -2) were much lower, less than 10 µg/l. Three weeks after injections dioxane concentrations were elevated at DP-5 and DP-6. At six weeks, measured levels were low at both DP-7 and DP-8.

- No significant levels of persulfate were measured at monitoring wells, except immediately after injections. Two to three weeks following injections sulfate concentrations began to significantly increase at wells 122-60, IMW-1, and IMW-2. At IMW-2, the most northern monitoring location, sulfate appeared to be continuously increasing to nearly 1,600 mg/L as late as September 29 (the last sampling event) while sulfate concentrations at wells 122-60 and IMW-1 appeared to have stabilized from early August to September 29, 2016. Sulfate measurements at DP locations were generally lower than those detected at monitoring wells – though no measurements were made at these locations after August 5. The sulfate concentration at DP-7 (the highest among DP measurements) was 143 mg/L on August 5, 2016; 457 mg/L was measured on the same day at IMW-1, about five feet away and several feet farther from the IP2 injection point.

- Redox/ORP increased (became more positive) at the four monitoring wells by some 85 to 100 mV. Significant increases did not occur until about two weeks after injections. Redox values did not increase to positive values at any of the four wells other than 122-60, but appeared to be continuing to increase – as of September 29 – at IMW-1. Positive values were recorded at DP-8 in early August and at 161-60 in late September, but it was unclear (based on what was submitted in the November memorandum) if these values were higher than would be expected without the influence of oxidant injections.

- In general, Ecology agrees with other injection and post-injection observations made by Stericycle in Sections 3.2 through 3.4.

- Bench-scale microcosm studies indicated that native microorganisms in site groundwater are unlikely to significantly biodegrade 1,4-dioxane. Nor, at the bench-scale level, did it appear that the addition of oxygen releasing compound aided biodegradation rates for non-native microorganisms introduced into samples of site groundwater.

- Bench-scale studies suggested that bioaugmentation with the introduction of non-native CB1190 bacteria could potentially result in significant dioxane biodegradation.

Starting in Section 4 of the November 17 Pilot Study Work Plan, Stericycle proposes new pilot studies. Section 4.1 discusses the application of slow-release ISCO, utilizing persulfate, in the same general area targeted by the first ISCO pilot study (i.e., near well 122-60). Section 4.2 proposes a two-step bioaugmentation pilot study. During the first step (Stage 1), non-native

dioxane-degrading bacteria would be introduced into a single well, 127-75. If monitoring indicated effective biodegradation, the second step (Stage 2) would be conducted. This would entail bioaugmentation injection and monitoring in the vicinity of well 161-60. Two Stage 2 monitoring wells would be installed immediately downgradient of well 161-60, and cultures would be injected at four locations surrounding 161-60.

These study proposals are consistent with the discussions Ecology had with Stericycle last September. We generally agree with them. The following comments refer specifically to parts of Section 4 or its associated tables that Ecology either disagrees with or questions:

Comments

1. Pages 7 through 11, Section 4.1. Ecology provides the following remarks on Stericycle's proposals for a second ISCO field study:

   a) Well 122-75 is also in the vicinity of the second ISCO pilot study. It should therefore be included among the monitoring wells for the study.

      In addition, the four monitoring wells (122-60, -75, IMW-1, and -2) should be sampled shortly before the three candle-containing wells are installed (to obtain "baseline" data). Perhaps Stericycle planned to do this, but it was not obvious to Ecology during our review of Tasks 6 through 8 in the Work Plan.

   b) Ecology is hesitant to initiate this second pilot study near well 122-60 until groundwater conditions (redox, sulfate levels, etc.) have clearly stabilized and returned to June 2016 "baseline" conditions. Determining when the June 2016 conditions have been sustainably reached may be difficult, since there is considerable uncertainty about where the injected oxidant went.

   c) As noted above, well 122-75 should be added to the study's group of monitoring wells (for both baseline and post-candle installation monitoring). In addition, Section 4 does not appear to discuss the monitoring of the three new wells (IP5, 6, and 7). We believe these wells should be included among the study's monitoring points. If they are sampled at the same frequency as the other wells (for persulfate, dioxane, etc.), it will better enable us to determine – over time – if there has been a relatively steady release of reagent.

   d) The Work Plan proposes to monitor for 9-12 months. This may be long enough to capture: a) any 1,4-dioxane rebound, and b) the return to baseline conditions for groundwater geochemistry and sulfate levels. Longer-term rebound monitoring should be performed as part of the quarterly monitoring program, conducted for at least a year after study completion.

   e) Analytes associated with ISCO monitoring should include metals (in addition to those proposed). While last summer's study did not suggest significant metals mobilization, Ecology suggests that groundwater samples again be analyzed for selected metals such as arsenic and chromium to verify that slow-release oxidant application is also unlikely to result in increased metals' concentrations.

2. Page 12, Section 4.2. Ecology recommends injecting the bioaugmentation culture into both 127-40 and 127-75. Dioxane levels have also been elevated in the shallow-zone well.

   Culture introduction at 127-40 could be performed during Stage 2. Similarly to Stericycle's plans for the 161-60 study, multiple injection points could be associated with 127-40 (for increased "coverage") and new semi-permanent wells could be installed downgradient for treatment-effectiveness monitoring.

   In addition, 1,4-dioxane levels near well 161 have also been elevated in the shallow zone. During Stage 2 Ecology recommends injecting the bioaugmentation culture into multiple shallow – as well as intermediate – zone locations near well 161.

3. Page 13, Section 4.2.1. Ecology agrees that the parties should work together on outreach activities performed prior to the bioaugmentation study. Although Stage 1 of the study involves fewer field activities, outreach should precede both stages of the study (not just Stage 2).

4. Page 13, Section 4.2.1, and Table 5. Proposed Stage 1 monitoring is briefly outlined in Table 5. Ecology concurs with the proposal to analyze groundwater samples for 1,4-dioxane, and to measure the "conventionals" described in Note 1. Prior to performing the study, however, Stericycle should identify the additional "genetic and nutrient analysis" that will be performed. These analyses need to be specified and more fully explained (will the analysis, e.g., go beyond qPCR analysis?). The relationship between these analytical results and indications of bioaugmentation success, and how Stericycle/Sentinel will ensure that the resulting data quality meets project needs, must be clarified before the study begins.

5. Page 13, Section 4.2.1, and Page 15, Section 4.2.3. Ecology agrees that the objectives of Stage 1 are to: a) determine if bioaugmentation can successfully degrade 1,4-dioxane at well 127; b) provide information for identifying "which bacteria are thriving" and "how long" the dioxane-degraders survive/thrive; and, c) decide if bioaugmentation on a larger scale is "worthwhile." Prior to performing Stage 1, however, the parties should have a clearer idea of how the study data will specifically be used to make these determinations, and what criteria will be used to define Stage 1 *success*.

6. Page 13, Section 4.2.1. Prior to performing Stages 1 and 2 of the study, Stericycle should determine whether "nutrients" or other "additives" will accompany the injected cultures. If so, they should be identified and their purpose explained.

7. Page 15, Section 4.2.3. It is not clear why Stericycle is proposing to inject 10 liters – rather than some other volume – of culture into well 127-75. Prior to the study the company must explain:
   - why 10L has been chosen,
   - what ex situ cell density this corresponds to,

- what the initial in situ cell density goal is (for well 127-75), and why this goal has been chosen,
- what the in situ cell density goals (for well 127-75) are for various time intervals following injection, and
- what the optimum injection flow rate will be (and why 2 L/min was selected as the upper limit of the "extraction" flow rate).

8. Page 15, Section 4.2.3. In the last paragraph of the Stage 1 section five post-injection monitoring events are proposed (at one week, two weeks, one month, and then quarterly for at least two rounds). Table 5, however, only identifies four post-injection events for Stage 1 study. The apparent discrepancy should be explained/corrected.

9. Pages 15 and 17. In the first paragraph of the Stage 2 discussion Stericycle proposes to monitor groundwater with wells 161-60, IMW-3, and IMW-4. The Work Plan states that the timing of monitoring events will be based on Stage 1 results, but assumes there will be four such (post-injection) events.[1] Ecology agrees that monitoring frequency, as well as the study's overall monitoring period, should be informed by Stage 1 results. Based on what is presented in Section 4.2, however, Ecology is unable to say at this time whether monitoring schedules similar to those proposed in Section 4.2.4 for Stages 1 and 2 are appropriate. As noted in Comments #4 and 5, prior to performing Stage 1 the parties should have a clearer idea of how the study data will be used to assess bioaugmentation performance. Then, based on these criteria and Sentinel expectations regarding how long it will take the microorganisms to establish themselves, begin degrading dioxane, and continue dioxane degradation (i.e., the degradation rate), a monitoring plan for this Stage can be developed. Likewise, proposals in the Stage 2 monitoring plan should be based on the results from Stage 1 and the criteria chosen for evaluating Stage 2 performance.

10. Page 17, Section 4.2.3. It is reasonable, as the Work Plan states, to set the maximum injection pressure at a value well below pressures capable of causing hydraulic fracturing (45 psi, for example). Although earlier in the Work Plan it is stated that CB1190 should tolerate injection pressures up to at least 40 psi, the maximum Stage 2 injection pressure should be selected in consultation with Sentinel to ensure optimum culture viability.

11. Page 17, Section 4.2.4. Please see monitoring-related comments 4, 5, and 9 above.

    In addition, no existing monitoring wells screened in the shallow/intermediate zones are located immediately upgradient of well 161. During Stage 2 it would therefore be advisable to include a new upgradient monitoring point (a semi-permanent well, e.g.) to provide measurements of 1,4-dioxane groundwater concentrations unaffected by the introduced culture.

[1] Although Table 5 appears to indicate that there will be five post-injection monitoring events for Stage 2 (and four for Stage 1).

12. Table 1. Prior to performing the studies proposed in the November 17 Pilot Study Work Plan, Stericycle should:

    - confirm that the July 7 ORP value for samples collected at well 122-75 was actually +42.8 mV; and,
    - provide pre-September 2016 monitoring information for well 161-60. In particular, it would be helpful to know specific conductivity, ORP, and 1,4-dioxane concentration values for the preceding year.

13. Table 3. Prior to performing the next ISCO study, Stericycle should provide an explanation for the June 24 10:40 to 10:55 IP-1 and IP-3 pressures and flowrates. According to the table pressures were increased from 10-20 to 22 psi at 10:40. The resulting flowrates were then measured to be 1.8 to 2 gpm. Pressures fell to 8 psi 15 minutes later without a diminishment in flowrates.

    Stericycle should explain:

    - whether a) the injection pressures were reduced at 10:55 to 8 psi at IP-1 and IP-3 in order to determine a minimum pressure capable of achieving an acceptable flowrate, or b) the pressure was observed to drop during the injection without making intentional adjustments;
    - why at both injection points an injection pressure of 8 psi resulted in no diminishment of the flowrate obtained at 22 psi (in fact there was a slight increase in flowrate at the much lower pressure); and,
    - why pressure readings were 28-30 psi during the second batch injection at IP-4, while there were much lower pressures (5 to 10 psi) during the other four injections (depths?) at IP-4. IMW-2's lithologic log (the closest well to IP-4) does not indicate that the second injection was likely directed into a finer grained formation (in comparison to the other 4 intervals).

14. Table 4. Section 4.1.4 (page 11) states that there will be five monitoring events (one month, 6 weeks, and quarterly for three additional events). The first column of the table should have therefore referred to Events #1 through #5.

15. Table 5. Prior to performing the ISB studies, Stericycle should confirm that the sampling depth for Stage 1 is 65 to 75 feet bgs (not 50'-60').

    In addition, as noted in Comments above, the monitoring events identified in the table's first column appear to be inconsistent with the text in Sections 4.2.3 and 4.2.4.

Ecology suggests that the parties meet – or hold a conference call – following your receipt of today's letter. During the meeting we can discuss the comments above and determine next steps for the project (such as whether the November 17 Pilot Study Work Plan should be revised, or whether there is an alternative approach for memorializing work plan changes arising from our meeting discussion). If you have any questions about today's letter, or wish to schedule a

follow-up conference call or meeting, please contact me at either (425) 649-4449 or ejon461@ecy.wa.gov.

Sincerely,

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