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DEPARTMENT OF ECOLOGY
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June 10, 2020

Gary L. Zimmerman
Golder Associates Inc.
18300 NE Union Hill Road, Suite 200
Redmond, WA 98052-3333

Re: White Paper on 1,4-Dioxane detection, occurrence, and evaluation of remedial alternatives at the Landsburg Mine Site

Dear Gary Zimmerman:

In a letter dated January 17, 2020, the Department of Ecology (Ecology) made the determination that concentration thresholds (triggers for remedial action) for 1,4-dioxane had been exceeded at the north portal wells, in accordance with Exhibit D of the Cleanup Action Plan (Compliance Monitoring Plan). This stemmed from the addition of 1,4-dioxane to the suite of chemicals analyzed in groundwater, beginning in November 2017. The addition of 1,4-dioxane was made in response to public comments received on the draft Cleanup Action Plan (CAP) in 2013.

Ecology required the PLPs to begin implementing contingency actions pursuant to the Contingent Groundwater Extraction and Treatment System Plan (Exhibit D, Part C). (*See* Consent Decree Section VI.A.4 and Exhibit D, Part A, at A-6 (step #6)). The first step involved producing a 30% Engineering Design Report (EDR) for an extraction and treatment system that is tailored to the 1,4-dioxane contamination detected in monitoring wells LMW-2, LMW-4, and LMW-12. In its letter, Ecology gave the PLP Group and the consultant for the PLP Group an opportunity to respond to this determination and collaboratively discuss potential system designs that will suitably remediate the 1,4-dioxane contamination discovered at the site.

The PLP Group submitted a 30% EDR and White Paper in response to Ecology's letter. The April 10, 2020 White Paper, titled "1,4-Dioxane Detection, Occurrence, and Evaluation of Remedial Alternatives at the Landsburg Mine Site" evaluated the implementation of contingent groundwater extraction and treatment for 1,4-dioxane at the north portal wells, assessed relative advantages and disadvantages, and discussed potential alternative system designs that would adequately remediate the 1,4-dioxane contamination at the site.

Ecology has reviewed the White Paper concurrently with the 30% EDR. Based on the arguments in the White Paper, Ecology is largely in agreement that implementing the contingent

groundwater extraction and treatment system under the existing conditions can be expected to have significant adverse environmental impacts and disproportionately high financial costs, with "minimal to no reduction in risk" based on low levels and limited extent of the 1,4-dioxane. Therefore, an alternate approach specific only to 1,4-dioxane could be implemented with an equivalent or better degree of protectiveness and permanence.

Ecology would agree that implementing the proposed remedial actions outlined in the White Paper are suitable actions that can be taken to address the problem:

- continue capping the wastes at the northern trench area but with a more impermeable geomembrane cover
- increased groundwater monitoring of north portal wells including off-site sentinel well located nearer to Cedar River
- connecting the Contingency Plan discharge pipe from the north contingent treatment pad to the Soos Creek sewer line

However, Ecology has the following recommendations in addition to what the PLP Group proposed:

- Expand monitoring of off-site sentinel wells to all three wells (LMW-20, LMW-21, and LMW-22).

- Evaluate the full analytical suite of chemicals tested at the site to ascertain that this special situation applies only to 1,4-dioxane and that there are no other chemicals with concentrations at or above the trigger levels of the cleanup action plan (Exhibit D. Compliance Monitoring Plan). Ecology will perform its own evaluation and compare results with the PLP Group evaluation.

- Except for the documented 1,4-dioxane exceedances at the northern portal wells, the trigger levels and contingent actions pursuant to the Contingent Groundwater Extraction and Treatment System Plan (Exhibit D, Part C) shall be strictly enforced for all other contaminants of concern at this area of the site, and will be strictly enforced for all contaminants of concern (including 1,4-dioxane) at the rest of the site. Should a surge of 1,4-dioxane be detected coming from the interior of the former mine above the concentration levels and locations described in the White Paper and the August 16, 2020 Technical memorandum titled "Pre-Remedial Action 1,4-Dioxane Detection at the Landsburg Mine Site", the contingent groundwater extraction and treatment system shall be implemented in strict accordance with the cleanup plan.

- Remedial actions should more actively address the 1,4-dioxane exceedances, especially at the conditional point of compliance. Therefore, Ecology recommends that In Situ Bioremediation (ISB), including cometabolic bioremediation, should be explored. These technologies are widely mentioned as possible remediation technologies especially for low concentrations of 1,4-dioxane. ISB and/or bioaugmentation can be applied using well injections at or near problem wells.

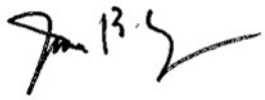
- Ecology recommends that an experienced environmental microbiologist or remediation expert who specializes in bioremediation perform an evaluation of ISB and/or bioaugmentation at the site. Scope of work may include microcosm, bench scale and pilot studies to determine if this approach would effectively remediate the 1,4-dioxane exceedances at the site.

- Ecology has attached notes and reference links on bioremediation technologies specific to remediating low concentrations of 1,4-dioxane in groundwater.

This letter constitutes initial comments on the White Paper and will be followed up with a final decision letter on the White Paper. At present, the deadline to file for dispute resolution is set to occur no later than 30 days following receipt of Ecology's final decision on the White Paper. Please wait for Ecology's final decision letter on the White Paper for next steps on this issue.

Ecology appreciates the cooperative manner by which the PLP Group is working with the agency on this issue. Please do not hesitate to contact me at jerome.cruz@ecy.wa.gov or (425) 649-7094 if you have any questions or concerns.

Sincerely,



Jerome B. Cruz
Site Manager
Toxics Cleanup Program, NWRO

Enclosure

cc: William Kombol, Palmer Coking Coal
Ivy Anderson, AGO-Ecology Division
Robert Warren, Ecology

Enclosure

Notes and links on ISB and Bioaugmentation to remediate low levels 1,4-dioxane in groundwater

- ***Enhanced Bioremediation*** In situ bioremediation (ISB) may be used to degrade 1,4-dioxane with the enhancement of existing or planted microbes that can degrade 1,4-dioxane. Recently, 1,4-dioxane has been shown in biotraps and in bench scale studies to be biologically degraded using in situ co-metabolic processes (Li et al., 2010 and 2013)[1]. Co-metabolic degradation can be accomplished by injecting a fuel or alcohol substrate such as tetrahydrofuran, propane, methane, 1-butanol, or 1-propanol into the groundwater. The biodegradation of 1,4-dioxane through co-metabolic processes is a relatively new development in the environmental remediation field. Drawbacks of the technology include the potential for indigenous microorganisms to outcompete 1,4-dioxane degraders for substrate. Depending on the substrate used, potentially explosive or hazardous conditions can be created. This technology has not been implemented within fully developed urban areas and has not been applied in source areas.
- ***Bioaugmentation*** Bioaugmentation is an in situ remedial technology in which microorganisms, specifically adapted for degradation of the constituent of interest are introduced to the affected groundwater. Bioaugmentation could be conducted using anaerobic or aerobic biological microorganisms. Under aerobic conditions, the microorganisms *Mycobacterium vaccae* JOB5 and *Pseudonocardia* K1 have been observed degrading 1,4-dioxane in industrial sludge. Both bacterial strains *Pseudonocardia dioxanivorans CB1190* and *Rhodococcus strain 219* have been shown to be capable of using 1,4-dioxane as a sole carbon source or to co-metabolically degrade 1,4-dioxane with another substrate (Mahendra and Alvarez-Cohen, 2006[2]). Any microorganisms that may degrade 1,4-dioxane would need to be evaluated prior to the introduction of the microorganism. Injection wells or push probes are typically used for injecting the microorganisms. The culture added to the subsurface would then need to be capable of competing with indigenous organisms for nutrients and substrate. In many bioaugmentation applications, the added organisms do not compete successfully with indigenous organisms and require the addition of substrate to favor the target microorganisms.
- See aerobic cometabolism section at http://www.environmentalrestoration.wiki/index.php?title=Biodegradation_-_1,4-Dioxane

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[1] Li, Menryan, Stephanie Fiorenza, James R Chatham, Shaily Mahendra, and Pedro J.J. Alvarez, 2010, 1,4-dioxane biodegradation at low temperatures in Arctic groundwater samples, *ScienceDirect*, February.
Li, Menryan, Jacques Mathieu, Yu Yang, Stephanie Fiorenza, Ye Deng, Zhili He, Jizhong Zhou, and Pedro J.J. Alvarez, 2013, Widespread Distribution of Soluble Di-Iron Monooxygenase (SDIMO) Genes in Arctic Groundwater Impacted by 1,4-dioxane, *Environmental Science and Technology*, ACS Publications, August 2.

[2] Mahendra S, Alvarez-Cohen L. Kinetics of 1,4-dioxane biodegradation by monooxygenase-expressing bacteria. *Environ Sci Technol*. 2006;40(17):5435-5442. doi:10.1021/es060714v

- **Example Approach:** Test ISB with bioaugmentation consisting of baseline injection and sampling with both to be conducted at a single well as a basic test of the viability of the 1,4-dioxane degrading cultures for use in-situ (see Technical Memorandum: ISB Phase I and ISCO Phase II Results and Downgradient Area Pilot Study Work Plan GEORGETOWN FACILITY SEATTLE, WASHINGTON November 17, 2016 Prepared by: DALTON, OLMSTED, & FUGLEVAND)
- Researchers recently identified a bacteria, called "CB-1190", that is capable of using 1,4-dioxane as a primary substrate, i.e. the CB-1190 bacteria can "eat" 1,4-dioxane. There are now commercially available tests that can be performed to see if CB-1190 is present at field sites. At sites where it is already present in groundwater, 1,4-dioxane degradation may already be occurring, and may be enhanced by injection of oxygen or other nutrients. At sites where CB-1190 isn't present, it could be added via bioaugmentation. https://trihydro.com/news/news-details/2017/05/30/emerging-contaminants-1-4-dioxane-biodegradation
- 1,4-Dioxane Biodegradation at Low Concentrations Geosyntec Authors: Chao Zhou, Sandra Dworatzek https://www.geosyntec.com/consultants/publications/69-publications/5983-1,4-dioxane-biodegradation-at-low-concentrations