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To: Shannon Harbour, PE
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RE: Revised Technical Memorandum: Calculation of Leaching-Based, Site-Specific Levels (LSSLs) for the Soil-to-Groundwater Pathway Using NDEP Guidance, Tronox LLC, Henderson, Nevada

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INTRODUCTION

This revised technical memorandum provides a screening evaluation of the potential for leaching of site-related chemicals (SRCs) from soil to groundwater at the Tronox facility in Henderson, Nevada (the Site). The revised memorandum incorporates comments received from the Nevada Division of Environmental Protection (NDEP, January 13, 2011) after their review of the November 18, 2010 original Tronox submission. Both the original and revised evaluations incorporate the methods presented in the *Soil to Groundwater Leaching Guidance* from the Nevada Division of Environmental Protection (NDEP), dated January 16, 2010 (guidance). This screening evaluation of leaching from soil to groundwater was conducted as discussed in telephone conversations between representatives of Tronox, Northgate, and NDEP on February 12, 17, and 23, 2010. Additional discussions were held with NDEP and Paul Hackenberry of Paul Hackenberry & Associates on April 8 and July 16, 2010 regarding methods for estimation of infiltration rates for developed land. The purpose of this leaching evaluation is to identify chemicals of potential concern (COPCs) that have the potential to leach from unsaturated soil into shallow groundwater at the Site. Upon NDEP's review and concurrence with the evaluation, source control measures for leaching concerns will be addressed using remedial alternatives appropriate for the COPCs.

A summary of revisions prompted by NDEP's comments on the technical memorandum is provided in a "response to comments" format in Attachment 1.

SCREENING EVALUATION BASED ON NDEP GUIDANCE

The guidance outlines the following progression of steps for evaluation of the soil-to-groundwater leaching pathway:

1. Comparison of Site soil concentration data with leaching-based, basic comparison levels (LBCLs), which are calculated using generic default values as input parameters for the soil-water partitioning (SWP) equation;
2. Comparison of Site soil concentration data with leaching-based, Site-specific levels (LSSLs), which are calculated using Site-specific chemical and soil properties in the SWP equation;
3. Unsaturated zone fate-and-transport modeling, employing Site-specific data; and
4. Synthetic precipitation leaching procedure (SPLP; U.S. EPA, 1994) testing, as required to support either the SWP equation or unsaturated zone fate-and-transport modeling.

This memorandum presents the results of the first two of these steps used to evaluate COPCs for the soil leaching to groundwater pathway. The methods for selection of organic and inorganic COPCs for the leaching evaluation are described in detail in Attachments 2 and 3.

METHODS USED TO SELECT CHEMICALS OF POTENTIAL CONCERN FOR THE LEACHING EVALUATION

The data set evaluated for leaching in RZ-A through RZ-E includes Phase A and Phase B samples collected from the Quaternary alluvium (Qal) between the ground surface and the contact with the Upper Muddy Creek formation (UMCf).

As an initial step, and in accordance with previous discussions and correspondence with NDEP, Site soil concentrations of metals were initially screened by comparison with the background dataset (RZ-A) approved by NDEP to select chemicals for further evaluation. Methods and results of the background metal evaluation are provided in Attachment 2.

Metals retained for further evaluation, as well as organics, were then evaluated in accordance with NDEP guidance by comparing Site soil concentration data with LBCLs (NDEP, 2009). For chemicals without established LBCLs, generic LBCLs were calculated using default values as input parameters for the soil-water partitioning (SWP) equation (Attachment 3). For some metals, LBCLs were adjusted based on the hierarchy

of risk-based groundwater concentrations (RBGCs) approved by NDEP for this project.[1] Attachment 3 describes in detail the parameters and methods used to calculate generic and adjusted LBCLs. COPCs that did not exceed LBCLs using a dilution attenuation factor (DAF) of 20 were not carried forward for further analysis (Attachment 2). The screening tables also include comparisons of Site soil concentration data with LBCLs for DAF=1, in accordance with the guidance.

The selection of COPCs for inorganic and organic chemicals is summarized below. Inorganic chemicals selected as COPCs are summarized by RZ area and depth, to be consistent with the background comparisons in Attachment 2, Tables 5A through 5D. Organic COPCs are selected based on a Site-wide comparison of soil concentrations with LBCLs for RZ-A through RZ-E (Attachment 2, Table 6), and are summarized following the inorganic COPCs.

Inorganic Chemicals Selected as COPCs for Leaching Evaluation

Inorganic COPCs for RZ-B through RZ-E were selected using the steps described in Attachment 2. The depth intervals for screening of inorganic COPCs are based on the statistical background comparisons presented in Attachment 2. The selection of inorganic COPCs for the leaching evaluation is summarized in Attachment 2, Tables 5A through 5D.

Perchlorate was selected as a COPC in all RZs for all depth intervals in the Qal, based on perchlorate's exceedance of the calculated generic LBCL for a dilution attenuation factor (DAF) of 20, as described in Attachment 3.

In addition to perchlorate, the inorganic COPCs for each RZ are the following:

- Antimony: RZ-C (0-10 feet below ground surface [fbgs]); RZ-E (0-10 fbgs)
- Arsenic: RZ-B (0-2 fbgs, 2-10 fbgs); RZ-C (0-2 fbgs); RZ-E (0-2 fbgs)
- Barium: RZ-C (0-10 fbgs); RZ-D (0-10 fbgs)
- Boron: RZ-C (0-10 fbgs); RZ-D (0-10 fbgs)
- Chromium (total): RZ-C (0-2 fbgs); RZ-D (0-2 fbgs); RZ-E (0-2 fbgs)
- Chromium (VI): RZ-C (0-10 fbgs, 10 fbgs to UMCf)
- Cobalt: RZ-C (0-10 fbgs, 10 fbgs to UMCf); RZ-E (0-10 fbgs)

[1] In accordance with minutes of the meetings with NDEP on February 12 and 17, 2010, the following hierarchy was used for RBGCs: 1) primary Maximum Contaminant Levels (MCLs); 2) BCLs; and 3) secondary MCLs.

- Lead: RZ-C (0-10 fbgs); RZ-E (0-10 fbgs)
- Magnesium: RZ-B (10 fbgs to UMCf); RZ-C (0-2 fbgs); RZ-D (0-2 fbgs); RZ-E (0-2 fbgs)
- Manganese: RZ-B (0-10 fbgs); RZ-C (0-10 fbgs, 10 fbgs to UMCf); RZ-D (0-10 fbgs); RZ-E (0-10 fbgs)
- Molybdenum: RZ-C (0-2 fbgs)
- Thallium: RZ-C (0-10 fbgs)

Organic Chemicals Selected as COPCs for Leaching Evaluation

Organic COPCs were selected by screening Site-wide (RZ-A through RZ-E) soil concentrations against LBCLs for DAFs of 1 and 20 (Attachment 2, Table 6). The following organic COPCs exceeded LBCLs for DAF=20, and were retained for further evaluation of their leaching potential:

Organochlorine Pesticides (OCPs): 4,4'-DDE, 4,4'-DDT, Aldrin, alpha-, beta-, and gamma BHC (Lindane), and Dieldrin.

Semivolatile Organic Compounds (SVOCs): Benz(a)anthracene, benzo(b)fluoranthene, and hexachlorobenzene.

Volatile Organic Compounds (VOCs): 1,2,3-trichloropropane, benzene, carbon tetrachloride, chloroform, and 1,2,4-trichlorobenzene.

CALCULATION OF LEACHING-BASED, SITE-SPECIFIC LEVELS AND SCREENING OF SITE SOIL DATA

Attachment 3 describes in detail the parameters and methods used to calculate LSSLs. LSSLs for chemicals present above LBCLs were calculated using the SWP equation presented in the guidance, with Site-specific soil physical properties and chemical-specific DAFs. The DAFs, in turn, are based on hydrogeologic properties and the length of the chemical source (***L***) in the unsaturated zone. To determine the source lengths, we used the LBCL for DAF=20 to define the extent of source areas for each COPC. As shown on Tables 4A and 4B of Attachment 3, with the exception of perchlorate, the DAFs for inorganics and organics ranged from approximately 36 to over 700 when calculated using this definition of source length. These DAFs were then used to calculate LSSLs in the SWP equation, as detailed in Attachment 3.

Tables 1A-D and 2A-E provide tabulated results of the comparison of Site soil concentrations with LBCLs and LSSLs for inorganic and organic COPCs, respectively, for each RZ area. These tables show the number of samples containing chemicals at concentrations exceeding the LBCLs and LSSLs. For the inorganic chemicals, the screening of chemicals is carried out for the same depth intervals that were determined for the statistical background comparison (Tables 1A-D and Attachment 2).

In addition to perchlorate, the following COPCs were detected in Site soils at concentrations above their respective LSSLs, as shown in Tables 1A-D and 2A-E:

COPCs Exceeding LSSLs in RZ-A

- Inorganics: None
- Organics: Beta-BHC

COPCs Exceeding LSSLs in RZ-B

- Inorganics (0-2 feet bgs): Arsenic
- Inorganics (0-10 feet bgs): manganese
- Organics: Alpha- and beta-BHC

COPCs Exceeding LSSLs in RZ-C

- Inorganics (0-2 feet bgs): arsenic and magnesium
- Inorganics (0-10 feet bgs): cobalt and manganese
- Inorganics (>10 feet bgs to UMCf): cobalt and manganese
- Organics: Alpha- and beta-BHC, hexachlorobenzene, and chloroform[2]

COPCs Exceeding LSSLs in RZ-D

- Inorganics (0-2 feet bgs): magnesium
- Inorganics (0-10 feet bgs): manganese
- Organics: Alpha-, beta-, and gamma-BHC (Lindane), hexachlorobenzene, and chloroform[3]

[2] The LSSL is less than the LBCL for chloroform because the target risk-based groundwater concentration (RBGC) used to calculate the LSSL (0.0016 milligrams per liter [mg/L] is less than the RBGC used to calculate the LBCL (0.1 mg/L).

COPCs Exceeding LSSLs in RZ-E

- Inorganics (0-2 feet bgs): arsenic
- Inorganics (0-10 feet bgs): cobalt and manganese
- Organics: Alpha- and beta-BHC, Dieldrin, and chloroform[4]

SUMMARY AND CONCLUSIONS

Inorganic chemicals for the leaching evaluation for each RZ were identified by comparing Site soil concentration data to the RZ-A background dataset approved by NDEP in their August 17, 2010 letter. After the background comparison was completed, inorganic and organic COPCs were selected by comparison to LBCLs for DAF=1 and DAF=20. LSSLs were then calculated for each COPC using methods and procedures described in NDEP's January 16, 2010 guidance and in accordance with discussions and correspondence with NDEP. For each COPC and RZ, the number of Phase A and B soil samples that exceed the LSSLs are tabulated in Tables 1A-1D and 2A-2E. Upon NDEP's review of these initial steps of evaluating the soil-to-groundwater leaching pathway, we recommend proceeding with additional evaluation using Site-specific data (e.g., development of Site-specific Kd values; compiling empirical Site data relating soil quality to groundwater impacts) to refine the assessment of COPCs at the Site. Concurrently, source control measures for leaching concerns to groundwater will be identified and screened for technical effectiveness and implementability at the Site. Potential technologies that will be considered include *in situ* methods such as stabilization, soil flushing, bioflushing, gaseous electron donor injection, and monitored natural attenuation, and ex situ methods such as stabilization and anaerobic biotreatment.

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[3] See footnote 2. In RZ-D, chloroform did not exceed the LBCL for DAF=20, but 4 soil samples in RZ-D contained chloroform at concentrations greater than the LSSL.

[4] See footnote 2.

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ENCLOSURES

Tables

1A Screening of Inorganic Chemicals in RZ-B Using LBCLs and LSSLs

1B Screening of Inorganic Chemicals in RZ-C Using LBCLs and LSSLs

1C Screening of Inorganic Chemicals in RZ-D Using LBCLs and LSSLs

1D Screening of Inorganic Chemicals in RZ-E Using LBCLs and LSSLs

2A Screening of Organic Chemicals in RZ-A Using LBCLs and LSSLs

2B Screening of Organic Chemicals in RZ-B Using LBCLs and LSSLs

2C Screening of Organic Chemicals in RZ-C Using LBCLs and LSSLs

2D Screening of Organic Chemicals in RZ-D Using LBCLs and LSSLs

2E Screening of Organic Chemicals in RZ-E Using LBCLs and LSSLs

Figures

1 Remediation Zones

Attachments

1 NDEP Correspondence and Responses to NDEP Comments

2 Background Comparison and Selection of Chemicals of Potential Concern (COPCs) for the Soil-to-Groundwater Leaching Pathway

3 Input Parameters