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July 2, 2013

John Cleary, P.E.
Washington Department of Ecology jcle461@ecy.wa.gov
4301 N. Monroe St.
Spokane, WA 99205

RE: Odor Panel Analysis – June 27th & 28th, 2013
OS&E Project No. 1918-M-00
Project Name: Site L

Dear John:

This letter presents the results of the recent odor panel analyses conducted by Odor Science & Engineering, Inc. (OS&E) for your Site L project in Washington State. A total of twelve (12) odor emission samples were collected in duplicate by on-site personnel over the two day period June 26th and 27th, 2013. The odor samples were collected into Tedlar gas sampling bags. Immediately following sample collection each day the samples were shipped via overnight delivery service to OS&E's Olfactory Laboratory in Bloomfield, CT sensory analysis. The samples arrived under chain of custody requesting sensory analysis of one set of samples – using the duplicates as a back-up. Several bags arrived flat or had burst; however the duplicate sample was analyzed in each case.

Upon arrival the samples were analyzed by dynamic dilution olfactometry using a trained and screened odor panel of 8 members. The odor panelists were chosen from OS&E's pool of panelists from the Greater Hartford area who actively participate in ongoing olfactory research and represent an average to above average sensitivity when compared to a large population. The samples were quantified in terms of dilution-to-threshold (D/T) ratio and odor intensity in accordance with ASTM Methods E-679-04 and E-544-99, respectively. The odor panelists were also asked to describe the odor character of the samples at varying dilution levels. The odor panel methodology is further described in Attachment A.

The results of the odor panel test are presented in the attached Table 1.

We appreciate the opportunity to assist you on this project. Please feel free to call Martha O'Brien or me if you have any questions concerning these results.

Sincerely,
ODOR SCIENCE & ENGINEERING, INC.

Gary K. Grumley

Gary K. Grumley
Associate Scientist

Table 1. Results of dynamic dilution olfactometry analysis – June 27th & 28th, 2013
Washington Department of Ecology – Project: Site L
OS&E Project No. 1918-M-00

Sampling Information			Odor Conc. D/T(1)	Stevens' Law Constants(2)		Odor Character(3)
Date	Time	ID		a	b	
Day 1						
06/26/13	8:05	ASP Biofilter	115	.59	.68	sour garbage, wet wood, pencil shavings, wet dirt, carrots, sour chemical, plastic
06/26/13	9:25	Tipping & ASP Biofilter	82	.66	.76	sour, composted garbage, cut lumber, tree bark, dried tobacco, paint, car oil, sour chemical, kerosene
06/26/13	9:45	Tipping & ASP Biofilter (Duplicate)	69	.72	.77	sour, composted garbage, wood chips, pencil shavings, dried tobacco, sour chemical, kerosene, plastic
06/26/13	11:40	Fresh ASP	4,212	.41	.81	sweet, sour, garbage, fermented garbage, detergent, oranges, chemical, Mr. Clean®
06/26/13	12:30	7 Day ASP	27	.60	.79	sour, rotten vegetation, earth, wet dirt, cigars, rusty metal, NH_3
06/26/13	15:00	Finished Unscreened Pile	16	.62	.93	earthy, dirt, burnt trash, floor polish, cigar, detergent, sour chemical, urine
Day 2						
06/27/13	8:05	Mass Bed- NE Corner	89	.66	.77	leaf/grass compost, rotten vegetables, sour garbage, spoiled milk, burnt popcorn, bleach
06/27/13	9:15	Mass Bed- NW Corner	38	.70	.76	leaf/grass compost, rotten vegetable garbage, bleach, stagnant water, dirty sink, sour milk, urine
06/27/13	10:25	Mass Bed – Middle W	352	.72	.73	sour, leaf/grass compost, rotten garbage, rotten vegetables, rotten corn, wet dirt, earthy, rusty metal
06/27/13	11:45	Mass Bed- Middle S	418	.69	.96	leaf/grass compost, rotten vegetables, sour garbage, wet grass, wet dirt, earthy, tobacco, bleach
06/27/13	13:00	Mass Bed- Middle E	902	.66	.76	rotten garbage, rotten potatoes, rotten peanuts, decaying fruit, spoiled milk, sour molasses, earthy
06/27/13	14:10	Equipment Blank	17	.48	.95	garbage, earthy, wet dirt, , wet grass, geraniums, musty, moldy, metal, plastic

1. D/T = dilutions-to-threshold
2. Stevens' Law correlates odor concentration (C) and odor intensity (I): $I = aC^b$. The constants a and b were determined by regression analysis based on the intensity ratings of the odor panel at varying dilution levels. I = 0-8 (based on the n-butanol intensity scale), C = odor concentration (D/T) typical of ambient odor levels.
3. Summary of all odor character descriptors used by the odor panelists at varying dilution levels.

ATTACHMENT A
Odor Science & Engineering, Inc.
Odor Panel Methodology

Measurement of Odor Levels by Dynamic Dilution Olfactometry

Odor concentration is defined as the dilution of an odor sample with odor-free air, at which only a specified percent of an odor panel, typically 50%, will detect the odor. This point represents odor threshold and is expressed in terms of "dilutions-to-threshold" (D/T).

Odor concentration was determined by means of OS&E's forced choice dynamic dilution olfactometer. The members of the panel who have been screened for their olfactory sensitivity and their ability to match odor intensities, have participated in on-going olfactory research at OS&E for a number of years.

In olfactometry, known dilutions of the odor sample were prepared by mixing a stream of odor-free air with a stream of the odor sample. The odor-free air is generated in-situ by passing the air from a compressor pump through a bed of activated charcoal and a potassium permanganate medium for purification. A portion of the odor free air is diverted into two sniff ports for direct presentation to a panelist who compares them with the diluted odor sample.

Another portion of the odor-free air is mixed in a known ratio with the odor from the sample bag and is then introduced into the third sniff port. A panelist is thus presented with three identical sniff ports, two of which provide a stream of odor-free air and the third one a known dilution of the odor sample. Unaware of which is which, the panelist is asked to identify the sniff port which is different from the other two, i.e., which contains the odor. The flow rate at all three nose cups is maintained at 3 liters per minute.

The analysis starts at high odor dilutions. Odor concentration in each subsequent evaluation is increased by a factor of 2. Initially a panelist is unlikely to correctly identify the sniff port which contains an odor. As the concentration increases, the likelihood of error is reduced and at one point the response at every subsequently higher concentration becomes consistently correct. The lowest odor concentration at which this consistency is first noticed, represents the **detection odor threshold** for that panelist.

As the odor concentration is increased further in the subsequent steps, the panelist becomes aware of the odor character, i.e. becomes able to differentiate the analyzed odor from other odors. The lowest odor concentration at which odor differentiation first becomes possible, represent the **recognition odor threshold** for the panelist. Essentially all of OS&E's work is done with recognition odor threshold. By definition the threshold odor is equal to 1 D/T (i.e. the volume of odorous air after dilution divided by the volume before dilution equals one).

The panelists typically arrive at threshold values at different concentrations. To interpret the data statistically, the geometric mean of the individual panelist's thresholds is calculated.

The olfactometer and the odor presentation procedure meet the recommendations of ASTM Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series of Limits (ASTM E679-04). The analysis was carried out in OS&E's Olfactory Laboratory in Bloomfield, Connecticut.

Odor Intensity

Odor intensity is determined using reference sample method with n-butanol as the reference compound (ASTM Method E-544-99). The n-butanol odor intensity scale is based on n-butanol vapor as odorant at eight concentrations. The concentration increases by a factor of two at each intensity step, starting with approximately 15 ppm at step 1.

Odors of widely different types can be compared on that scale just like the intensities of the lights of different colors can be compared to the intensity of standard, e.g. white light. Odor character and hedonic tone are ignored in that comparison. Odor intensities are routinely measured as part of the dynamic dilution olfactometry measurements. The n-butanol vapor samples are presented to the panelists in closed jars containing the standard solutions of n-butanol in distilled water. The vapor pressure above the butanol solutions corresponds to the steps on the n-butanol scale. To observe the odor intensity, a panelist opens the jar and sniffs the air above the liquid. The panelist then closes the jar so that the equilibrium vapor pressure of butanol can be re-established before the next panelist uses the jar. The odor in the jar is compared with unknown odor present at the olfactometer sniff port.

The relationship between odor concentration and intensity can be expressed as a psychophysical power function also known as Steven's law (Dose-Response Function). The function is of the form:

$$I = aC^b$$

where:

I = odor intensity on the butanol scale
C = the odor level in dilution-to-threshold ratio (D/T)
a,b = constants specific for each odor

The major significance of the dose-response function in odor control work is that it determines the rate at which odor intensity decreases as the odor concentration is reduced (either by atmospheric dispersion or by an odor control device).

Odor emissions are used as input to an odor dispersion model, which predicts odor impacts downwind under a variety of meteorological conditions. Whether or not an odor is judged objectionable depends primarily in its intensity. The dose-response constants are used to convert predicted ambient odor concentration to intensity levels. OS&E experience has shown that odors are almost universally considered objectionable when their intensity is 3 or higher on the 8-point n-butanol scale. In general, the lower the intensity, the lower the probability of complaints.

Odor Character Description

Odor character refers to our ability to recognize the similarity of odors. It allows us to distinguish odors of different substances on the basis of experience. We use three types of descriptors, general such as “sweet”, “pungent”, “acrid”, etc. or specific references to its source such as “orange”, “skunk”, “paint”, “sewage”, etc., or to a specific chemical, e.g. “methyl mercaptan”, “butyric acid”, or “cyclohexane”. In the course of the dynamic dilution olfactometry measurements, the odor panelists are asked to describe the character of the odors they detect.