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TECHNICAL MEMORANDUM

Date: October 1, 2007
To: Deanna Carveth/Snohomish County
From: Bob Rosain/Parametrix
Subject: Canola Dryer Test Summary
cc: Terrill Chang/URS
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Project Number: 553-1513-085-12-01
Project Name: Canola Dryer Testing Equipment Identification – Parametrix WA #12

Background

Snohomish County was interested in determining the feasibility of using landfill gas (LFG) generated at the closed Cathcart Landfill to fuel a commercial scale, canola seed dryer. Snohomish County farmers have shown considerable interest in growing canola seed to produce oil for use as a biofuel, but canola seed grown in western Washington must be dried to reduce its moisture content before storage or processing. Using LFG as a dryer fuel source would significantly reduce the cost to dry the seed when compared to traditional fuels (natural gas or propane). Further, productive use of waste LFG provides obvious environmental and social benefits.

The Snohomish County Solid Waste Department tasked Parametrix to research and identify viable canola seed dryers; plan and execute a field test to ascertain the viability of using LFG as a dryer fuel source (proof-of-concept); and determine, 1) the net effects of using this fuel source on the dried canola seed, and 2) the air quality issues associated with using this fuel source in a seed dryer when compared to the landfill's existing gas flare. Given the plan to crush and extract canola oil (for biofuel) from the dried seed and use the resultant seed hulls as cattle feed, there was a concern that some of the known LFG organic contaminants (volatile organic compounds – VOC's) might not be fully combusted and be adsorbed by the seed hulls rendering them unsuitable for cattle feed. There was a further concern that dioxins, known carcinogens, may also be generated by the combustion process and be adsorbed by the seed hulls. Hence the need for the analytical tests noted above.

Dryer Identification and Testing

Canola seed drying is practiced extensively in the northern Midwest states and in Saskatchewan, so there is a considerable base of information on the practice, and numerous manufacturers of commercial-scale seed dryers. After considerable searching and numerous discussions with one of the project's key stakeholders, Wolfkill Feed & Fertilizer Co. in Monroe, Washington, a small, used canola seed dryer was located in Saskatchewan, purchased by Wolfkill and brought to the Cathcart site. Wolfkill staff were instrumental in converting the dryer to utilize LFG, in working with farmers to obtain sufficient seed to test and in physically running the seed dryer tests. Snohomish County staff were instrumental in procuring and installing additional infrastructure to support the dryer test (LFG booster blower, instrumentation, and LFG piping to the dryer). Pursuant to the agreed scope of work, Parametrix provided project coordination, dryer research, auxiliary equipment specifications, installation engineering support, test observation, and analytical testing (through a subcontract to Amtest Air Quality, LLC).

The actual testing was conducted on August 6, 2007. A previously used, portable, seed dryer was procured and re-furbished by Wolfkill staff. The dryer was a GT-Model No. 380 (Gilmore & Tatge Mfg. Co., Inc, Clay Center, Kansas), direct-fired, canola seed dryer. Wolfkill moved the dryer to the Cathcart site and set it up as close to the LFG blower building as possible. The dryer burner was designed to utilize the low-BTU LFG fuel at a nominal flow of 250 SCFM and a nominal of line pressure of 15 psig. This required a booster blower, after-cooler, and associated controls to raise the existing LFG line pressure from 0.5 psig to 15 psig. Snohomish County staff were responsible for procuring and installing the blower and after-cooler (based on Parametrix specifications) and associated controls and piping to the seed dryer.

In general, the testing went as planned and Amtest was able to obtain the required samples of canola seed, before and after drying as well as monitor air emissions. Photographs of the testing were sent to the County under a separate cover and the Amtest analytical results are attached to this memo.

Test Results

The testing done on August 6th clearly provided the Proof-of-Concept results that were sought. That is, canola seed can be dried using a direct-fired, commercial canola seed dryer, utilizing LFG as the sole fuel source. Although the dryer operating conditions were not optimized, they were sufficient to provide proof-of-concept results. Some additional testing may still be required prior to moving forward with a full scale installation (see below).

The Wolfkill portable, batch-type seed dryer had a capacity of approximately 350 bushels, or eight tons of seed per batch. Unfortunately, there were only about two tons of seed ultimately available so the dryer ran at less than capacity for the test. However, it was agreed that this would have little bearing on the test results, other than being able to dry the volume of seed faster than a full load. Wolfkill analyzed the seed for moisture content before and after the test and confirmed that they were able to easily achieve the desired 6-7 percent moisture content. Before and after seed samples were also obtained for analytical testing. Amtest obtained before and after seed samples, arranged to have their analytical laboratory crush the seed, extract the resultant canola oil, and then analyze the remaining seed hulls for the same VOC's that were found in the raw and combusted LFG. As noted above, the seed hulls were also analyzed for dioxins. The canola oil was not analyzed for possible VOC's as its end use, that is, as a biofuel was deemed not to be a concern in this regard.

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Regarding the VOC analysis, the before and after canola seed samples collected were prepared as noted above and the remaining seed hulls analyzed using the standard EPA Method 8260B. In general, laboratory quality control (QC) results (i.e., duplicate results, surrogate and spike recoveries, etc.) were acceptable. However, the laboratory reported method blank contamination for two VOC analytes: Methylene chloride and toluene. Both of these compounds are routine atmospheric contaminants in environmental laboratories, and both also were detected in the seed samples. No other VOC compounds were detected in the two samples submitted.

Table 1 summarizes the blank and sample levels for these two compounds.

Table 1.

| Analyte | Method Blank (ng/g) | Dried Seed (ng/g) | Control (Undried) Seed (ng/g) |
|--------------------|------------------------|----------------------|----------------------------------|
| Methylene Chloride | 3201.03 | 3308.43 | 4056.62 |
| Toluene | 389.60 | 334.10 | 395.07 |

Given the similarity between the concentrations in the blank and seed samples, these results are most likely due to background contamination of the samples during analysis. As such, the results reported for the two seed samples should be considered non-detects (i.e., not present in the samples) and not considered further in any evaluation of the canola seed product.

The dioxin analysis is significantly more complex and deserves further explanation. However, the end result was that dioxin (what's known as 2,3,7,8 – TCDF) was not found in the undried or dried seed hull samples. However, there are seven polychlorinated dibenzo-*p*-dioxin (PCDD) congeners¹, ten polychlorinated dibenzo-*p*-furan (PCDF) congeners, and 12 polychlorinated biphenyl (PCB) congeners that exhibit “dioxin-like” toxicity. The most toxic and well studied of these congeners is 2,3,7,8-TCDD, which is often simply referred to as “dioxin.” The toxicity of other “dioxin-like” congeners are often evaluated based on their potency relative to 2,3,7,8-TCDD by using toxicity equivalence factors (TEFs). A TEF of 0.1, for example, means the congener has one-tenth the potency of 2,3,7,8-TCDD. Each congener concentration is multiplied by its respective TEF and then these products are summed to estimate the toxicity equivalence concentration (TEC)² (USEPA 2003):

$$TEC = \sum_{n=1}^k C_n * TEF_n \quad (1)$$

Where: TEC= toxicity equivalence concentration
C_n=concentration of congener n in an organism or its exposure medium (food, sediment, soil)
TEF_n= toxicity equivalence factor for congener n
k= number of toxic congeners in sample

The TEC can then be compared to a toxicity threshold or benchmark for 2,3,7,8-TCDD.

¹ In the case of PCDDs, PCDFs, and PCBs, a congener is a specific chemical within each of these families of compounds. Within each family of these compounds, each congener differs in the number and placement of chlorine atoms.

² In its draft framework for applying the toxicity equivalence methodology to for PCDDs, PCDFs, and dioxin-like PCBs in ecological risk assessment, the USEPA recommends use of the term “TEC” for defining toxicity equivalence concentrations (USEPA 2003). Other commonly used acronyms are TEq or TEQ.

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In the current project, the seven dioxin-like PCDDs and ten dioxin-like PCDFs were analyzed in both seed samples. Only octachlorodibenzo-*p*-dioxin (OCDD) was detected. Based on the detected mass of 3.67 pg in the dried seed sample and a sample weight of 10.0 g (100% solids), the concentration of OCDD in seeds was 0.367 pg/g dry wt. (parts per trillion). For humans, birds, and mammals, the TEF for OCDD is 0.0001, or one-ten thousandth the potency of 2,3,7,8-TCDD (USEPA 2003, 2005)³. Because none of the other dioxin-like congeners were detected, the TEC is based only on OCDD:

$$\text{TEC} = 0.367 \text{ pg/g dry wt.} \times 0.0001 = 0.0000367 \text{ pg/g dry wt.} \quad (2)$$

Of concern is whether this TEC is sufficiently high to pose a toxicity risk to cattle. Although 2,3,7,8-TCDD toxicity data are not available for cattle specifically, toxicity data for other mammals (such as rats) can be used as a surrogate measure in a screening-level assessment. As an additional line of evidence, the screening-level assessment also considered potential risks to birds that could feed on the seeds. It was assumed that cattle and birds could feed chronically and exclusively on the seeds. According to the screening benchmarks provided in ORNL (1996), the no observed adverse effect levels (NOAELs) for mammals (rat) and birds (pheasant) exposed to 2,3,7,8-TCDD are doses of 1.0×10^{-6} and 1.4×10^{-5} mg per kg body weight per day (mg/kg-d), respectively. Because the sensitivity of mammals to chemicals expressed as a dose is dependent on body size, the mammalian NOAEL of 1.0×10^{-6} mg/kg-d was adjusted to 1.6×10^{-7} mg/kg-d using estimates of relative body weights for rats and cattle and Equation 4 in ORNL (1996).

To calculate the TEC dose, the first step is to identify food ingestion rates and body weights for cattle and a representative bird species. For cattle, CEPA (2000) identified a feed ingestion rate of 8 kg/d and body weight of 500 kg. For a representative bird, the food ingestion rate for a generic passerine bird can be estimated using the allometric equation in USEPA (1993). In this case, a body weight of 77 g was assumed, which is the size of a typical robin (USEPA 1993):

$$\text{FIR} = 0.398 \times \text{BW}^{0.850} = 16.0 \text{ g/day (dry wt.)} \quad (3)$$

Where: FIR= food ingestion rate
 BW= body weight (77 g)

Thus, the TEC concentration of 0.0000367 pg/g dry wt. results in cattle and representative bird doses of:

$$\text{Cattle Dose} = \frac{0.0000367 \text{ pg}}{\text{g dry wt.}} \times \frac{8 \text{ kg food dry wt.}}{500 \text{ kg}} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{\text{mg}}{10^9 \text{ pg}} = 5.9 \times 10^{-13} \text{ mg/kg - d} \quad (4)$$

$$\text{Bird Dose} = \frac{0.0000367 \text{ pg}}{\text{g dry wt.}} \times \frac{16.0 \text{ g food dry wt.}}{77 \text{ g}} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{\text{mg}}{10^9 \text{ pg}} = 7.6 \times 10^{-12} \text{ mg/kg - d} \quad (5)$$

The estimated doses of 5.9×10^{-13} mg/kg-d and 7.6×10^{-12} mg/kg-d for cattle and a representative bird, respectively, are approximately six to seven orders of magnitude less than their respective NOAELs. These results demonstrate that the OCDD concentration in seeds is sufficiently low, with a large margin of safety, to not pose an ecological risk to cattle or wildlife that could potentially consume the seeds.

³ Note that AmTest refers to a TEF of 0.001 for OCDD based on a 1989 USEPA report, but these have since been revised. In addition, it should be noted that the World Health Organization (WHO) is currently recommending a human health-based TEF of 0.0003 for OCDD (Van den Berg et al. 2006).

Likewise, because possible human exposures are expected to be negligible, the OCDD concentration would also not be of concern for human health.

From an air quality standpoint, the dryer burner inlet (raw LFG) and the burner outlet were analyzed for the full suite of VOC's (See Amtest report attached). These compounds are typically found in LFG but are sufficiently destroyed by the site's LFG flare, so the question was, would the dryer burner provide similar destruction efficiency. Unfortunately, the VOC destruction efficiency of the dryer could not be fully ascertained because there was no way to obtain a LFG mass flow rate exiting the dryer. The dryer configuration simply did not lend itself to this determination without considerable modification. However, the analytical results did indicate a significant reduction in VOC's across the dryer burner as expected, but a standard destruction efficiency (to compare to the existing flare) could not be calculated. This calculation and a means to obtain a mass flow rate will be required for any full scale, fully-permitted installation. However, such an installation will also be fully engineered and designed to accommodate this requirement unlike the temporary test conducted here. It should be noted that the County received a variance from the Puget Sound Clean Air Agency to conduct this one-time proof-of-concept dryer test.

Conclusions

Based on all of the above, the following conclusions can be reached:

1. LFG can be used to dry canola seeds in a direct-fired, commercial type grain/seed dryer.
2. While the LFG VOC contaminant concentrations were significantly reduced when combusted in the seed dryer, the dryer/burner destruction efficiency could not be fully ascertained in this test and will require further research, engineering and testing to assure compliance with anticipated air quality regulations for a full scale dryer installation.
3. Based on the tests run to date, there is no evidence of LFG contaminant transfer to the dried canola seed byproduct, or contaminant generation with this direct-fired, LFG fueled dryer.
4. A full-scale, direct-fired, LFG fueled seed dryer clearly appears feasible. However, unlike this proof-of-concept test, a full-scale installation must be specifically designed and engineered to utilize LFG (burner design, LFG pressure, airflow, residence time, etc) and meet applicable air quality regulations.

Recommendations

Based on the assumption that Snohomish County is interested in moving forward on the design and installation of a full-scale, direct-fired canola seed dryer using LFG, the following recommendations are offered:

1. Define the dryer size based on the foreseeable canola crop size and necessary dryer throughput. Input (undried) seed storage will likely be necessary, but the volume will be minimal to prevent germination. Dried seed storage requirements will be based somewhat on where the seed will be crushed and the ability to transport the seed to a crushing facility.
2. There are numerous types and manufacturers of direct-fired seed dryers. Given a defined size and throughput requirement, the dryer market should be further researched and a dryer type chosen that can optimize the use of LFG as a fuel source. It is assumed that there will be multiple manufacturers of the chosen dryer type such that a unit can be specified and competitive proposals obtained.
3. The Cathcart dryer will need to be specifically engineered to utilize LFG as a fuel source. Currently, dryers use either natural gas or propane and the dryer burners, supplemental airflow and all instrumentation and control systems are based on these fuels. Low BTU LFG, especially if its supplied at pressures lower than commercial natural gas or propane, will require a unique

burner design and possible other internal modifications. Further, the dryer will have to be able to sufficiently destroy known LFG contaminants (VOC's) to the same levels of the existing site flares.

4. Given the fact that Cathcart LFG production is declining, there may be a need to provide a supplemental fuel in the coming years if LFG cannot supply the total dryer requirement. This would likely be natural gas, and the dryer should be designed with this consideration.
5. Although there was no evidence of LFG contaminant transfer to the dried seed product in this proof-of-concept test, it is recommended that some additional tests be performed with seed and the existing Cathcart flare to re-confirm this observation. Considering the fact that this would be the first direct-fired, LFG fueled seed dryer in the country, additional, confirmatory tests appear to be a prudent course of action. It may also be advisable to involve the WSU Extension service in the effort to add their credibility to the additional tests.

Literature Cited

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