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Subject:
Review of Dioxin in Zucchini Exposure Estimates in the draft Health Consultation and Neighborhood Update issued by the Florida Department of Health for Surface Soil in the Vicinity of the Cabot Carbon-Koppers, Superfund Site in Gainesville, Florida,

Environmental

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Mr. Merchant:

The purpose of this letter is provide the results of ARCADIS's review and evaluation of the dioxin and furan in zucchini evaluations presented in the draft "Health Consultation, Surface Soil in the Surrounding Areas, Cabot Carbon-Koppers, Superfund Hazardous Waste Site, Gainesville, Alachua County, Florida, EPA Facility ID: FLD980709356" (draft Health Consultation (dHC)) prepared by the Florida Department of Health (FDOH) and Agency for Toxic Substances and Disease Registry (ATSDR), as well as the August 2013 "Neighborhood Update" issued by the FDOH on the same subject. As explained in further detail below, both the dHC and Neighborhood Update appear to be based on estimates of potential exposure that contain a conversion error in the calculations and on exposure and uptake assumptions that may not be appropriately derived. The result of these issues is a substantial overestimate of potential exposure and risk from consumption of homegrown zucchini. For the reasons stated below, ARCADIS recommends that FDOH and ATSDR update their calculations of potential risk associated with consumption of homegrown zucchini and further recommends that FDOH rescind the warning and correct the information communicated to the public in the Neighborhood Update.

In the dHC, FDOH and ATSDR conclude that the dose from eating zucchinis grown in soil with high off-Site dioxin concentrations near the former Koppers facility (70 parts per trillion (ppt)) would: "likely be too high to rule out the possibility of non-cancer illness", and further conclude that this zucchini exposure pathway could "result in a "low" increased cancer risk of 1×10^{-4}". In the Neighborhood Update, the FDOH recommends that residents living near the former Koppers facility limit consumption of zucchini grown in soil with 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalent (TCDD-TEQ) concentrations greater than 23 ppt.

The FDOH estimate of potential exposure to TCDD-TEQ via consumption of zucchini fruits is based on two key assumptions:

- Zucchini fruits will have a TCDD-TEQ concentration equal to 13.5 percent (%) of the soil concentration at the location where they are grown. The 13.5% soil to zucchini uptake ratio is taken directly from a study published in 1994 (Hulster et al., 1994)[1]; and

- The assumed zucchini intake rate (consumption) is 0.7 g/kg-day. This rate was obtained from Table 9-6 of the 2011 Exposure Factors Handbook (EFH) (USEPA, 2011)[2] and is based on the mean consumer-only intake rate of all cucurbits.

To estimate the potential TCDD-TEQ dose associated with consumption of zucchini (6×10^{-9} mg/kg/day), FDOH combined the above assumptions with an assumed soil concentration of 70 ppt using the following equation:

$$\mathbf{Dose}_{\mathbf{zucchini}} = Cs \times Uptake \times IR / CF1 \times CF2.$$

Where:

Cs = Concentration in Soil: 70 (ng dioxin / kg soil);

Uptake = Soil to Zucchini TCDD-TEQ Uptake Ratio from Hulster et al (1994): 0.135 (ng/kg zucchini per ng/kg soil);

IR = Zucchini Intake Rate: 0.7 (g zucchini/kg body weight-day);

CF1 = Conversion Factor: 10^3 kg/g; and

CF2 = Conversion Factor: 10^6 mg/ng.

To estimate the potential non-cancer risk associated with this exposure, the dHC compares the non-cancer dose derived using the above equation to the lowest observed adverse effect level (LOAEL) for 2,3,7,8-TCDD of 2×10^{-8} mg/kg/day

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[1] Hulster, A., Muller, J.F., and Marschner, H. 1994. Soil-Plant transfer of polychlorinated dibenzo-p-dioxin and dibenzofurans to vegetables in the cucumber family (Cucurbitaceae). Environmental Science and Technology, 28:1110-1115.

[2] USEPA. 2011 Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F. September 2011.

(USEPA 2013)[3]. This LOAEL was then divided by a safety factor of 10 to derive a no observed adverse effect level (NOAEL) of 2 x 10^{-9} mg/kg/day. The NOAEL was combined with the above TCDD-TEQ uptake ratio and daily consumption rate to derive the threshold soil TCDD-TEQ concentration of 23 ppt reported in the August 2013 Neighborhood Update (Randy Merchant, personal communication).

In addition to evaluating potential non-cancer risk associated with TCDD-TEQ in zucchini fruits, the dHC also evaluates potential cancer risk and reports those potential risks to be 1x10^{-4}. However, when the assumptions presented in the dHC are applied to the calculations used in the dHC, the estimated potential excess lifetime cancer risk is calculated at 6.9x10^{-5}, lower than the 1x10^{-4} reported in the dHC. The dHC categorizes the estimated cancer risk as "low". Because the potential cancer risk is characterized as "low" and because the threshold soil concentration of 23 ppt discussed in the Neighborhood Update is based on potential non-cancer risk, the review of the zucchini exposure evaluations presented in this letter focuses on the non-cancer calculations that were reported in the dHC and the Neighborhood Update, and is not focused on the estimate of potential cancer risk presented in the dHC. However, if the recommendations and corrections presented in this letter are applied to the potential excess lifetime cancer risk estimates, those estimates would decrease by at least 10-fold to less than 1x10^{-5} and would be categorized by FDOH as "very low" and in some cases by more than 100-fold and would be categorized by FDOH as "extremely low."

The remainder of this letter first describes an inconsistency in the units of the uptake and consumption assumptions used by the dose estimation presented in the dHC. Correcting this inconsistency decreases by 10-fold the estimated TCDD-TEQ exposure from consumption of zucchini. This correction also results in a 10-fold increase to the 23 ppt threshold soil concentration presented in the Neighborhood Update, resulting in a threshold soil concentration of 230 ppt – which is at least two times greater than any of the off-Site soil concentrations near the former Koppers facility. This correction alone would negate the need for any public health notice, and would do so without changing or modifying the conservative uptake and consumption assumptions that were used by FDOH. However, this letter goes on to describe additional information that suggests the assumptions (i.e., the uptake ratio and ingestion rate) used in the dHC to estimate potential exposure to TCDD-TEQ via

[3] USEPA, 2013. Integrated Risk Information System (IRIS) summary for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Accessed 2-13-13 at www.epa.gov/iris/subst/1024.htm. (As cited in the dHC.)

consumption of zucchini likely overestimate such exposure for soil in the vicinity of the Cabot Carbon-Koppers, Superfund Site (Site).

Dry weight to Wet Weight Conversion Correction

An inconsistency in units was identified during ARCADIS's review of the zucchini exposure calculations presented in the dHC and used in the derivation of the 23 ppt threshold soil concentration presented in the Neighborhood Update. As noted above, a zucchini consumption rate of 0.7 g/kg-day is used in these calculations, as well as a 13.5% soil to zucchini fruit uptake ratio. The 13.5% ratio is reported in Hulster et al. (1994) on a dry weight basis. However, the 0.7 g/kg-day consumption rate presented in the Exposure Factors Handbook (USEPA 2011) and used in the dHC and Neighborhood Update calculations is in units of wet weight (i.e., as-consumed or edible portion uncooked fruits and vegetables consumed per day or per eating occasion). As such, the units of the consumption rate differ from the units of the soil to zucchini uptake ratio used to estimate the zucchini TCDD-TEQ threshold soil concentration. These units need to be consistent for the estimates of potential exposure and risk to be accurate. In other words, to properly calculate potential exposure and risk, both the consumption rate and the assumed concentration of TCDD-TEQ in zucchini need to be expressed on either a dry weight basis or a wet weight basis. As explained below, mixing a combination of conflicting dry weight and wet weight exposure factors in the calculation of potential exposure and risk results in a substantial overestimate of potential exposure and risk.

The dry-weight to wet weight adjustment of the soil to zucchini uptake rate results in a wet weight uptake ratio of 1.35%, assuming the moisture content of zucchini fruits is 90% (Table 9-37 of the Exposure Factors Handbook, USEPA 2011). If this wet weight-based soil uptake ratio is combined with the assumed wet weight consumption rate of 0.7 g/kg-day, the resulting TCDD-TEQ dose from consumption of zucchini grown in soils with a 70 ppt TCDD-TEQ concentration is 6×10^{-10} mg/kg/day. This dose is 10-fold lower than that reported in the dHC and is 30-fold below the LOAEL used by FDOH in the dHC to evaluate the need to issue an advisory to the community about consumption of zucchini (not the 3-fold difference reported in the dHC where the conflicting units noted above were used). Correcting for the inconsistency in wet weight and dry weight units also results in a 10-fold increase in the calculation of the threshold soil concentration for TCDD-TEQ concentration in surface soils. Indeed, using uniform wet weight exposure assumptions, the threshold soil concentration for TCDD-TEQ would increase from

the 23 ppt reported in the Neighborhood Update to 210 ppt[4]. All off-Site residential soils to the north, west and south of the Site are well below this corrected threshold soil concentration, suggesting that no advisory for homegrown zucchini consumption is needed based on the assumptions presented in the dHC and Neighborhood Update.

Uptake rate by zucchini from soil

ARCADIS also reviewed Hulster et al. (1994) to determine if the uptake rates reported in the study were appropriate for use in the FDOH zucchini exposure assessment. As noted above, Hulster et al. (1994) report that zucchini fruits will have a TCDD-TEQ concentration equal to 13.5% of the soil concentration on a dry weight basis (estimated to be 1.35% on a wet weight basis, see above). The TCDD-TEQ uptake ratios (on either a dry or wet weight basis) reported by Hulster et al. (1994) are not appropriate for soils in the neighborhood to the west of the Site for several reasons.

- The source of the dioxins and furans in the Hulster et al. (1994) study (chloralkali residues) is different from the soils surrounding the Site. Different sources can have different bioavailability and different homologue and congener distributions. The dHC contains no information suggesting that the FDOH evaluated the bioavailability and homologue/congener distributions of the dioxins and furans detected in the Stephen Foster neighborhood compared to those used by Hulster et al. (1994). **Figure 1** shows a plot of the homolog distributions in the soil at an off-Site sample location near the former Koppers facility with 70 ppt of TCDD-TEQ (sampling location SS-55) compared to soil homolog distributions presented in Hulster et al. (1994). The two are clearly different. Soils at sampling location SS-55 have a much higher proportion of the OCDD and HpCDF homologues than soils used by Hulster et al. (1994). Compared to the soil at sampling location SS-55, the Hulster et al. (1994) soils have a higher proportion of all of the other homologue groups. This variation in congener distribution suggests that the

[4] Note that when the assumptions presented in the dHC are used to estimate the threshold soil concentration of 23 ppt reported in the Neighborhood update, ARCADIS's calculations result in an estimated threshold soil concentration of 21 ppt. With the corrected dry to wet weight conversion, the threshold soil concentration is 210 ppt. The remainder of this letter and accompanying tables use the 210 ppt threshold soil concentration.

soils evaluated and the uptake rates derived from soils in Hulster et al. (1994) are not directly applicable to soil in the vicinity of the former Koppers facility.

- The 13.5% uptake ratio on a dry weight basis (1.35% on a wet weight basis, see above for explanation) used by FDOH in its calculations is based on the TCDD-TEQ in the soils evaluated by Hulster et al. (1994). That ratio does not apply directly to TCDD-TEQ in soils to the west of the Site because, as shown in **Figure 1**, soils to the west of the Site have a unique homologue distribution (among other differences). Hulster et al. (1994) (as well as Inui et al. (2008)[5] and Zhang et al. (2009)[6] also cited in the dHC) indicate uptake rates differ among homologue groups and congeners. Therefore, all of these studies support the need to account for congener-specific differences in uptake when estimating the TCDD-TEQ concentration in zucchini. In **Table 1**, congener specific uptake rates reported by Inui et al. (2008) were combined with the congener-specific soil concentrations at location SS-55 near the former Koppers facility to estimate congener-specific and TCDD-TEQ concentrations in zucchini as well as a range of TCDD-TEQ uptake rates based on the different soils evaluated by Inui et al. (2008).

- Hulster et al. (1994) only report uptake for homologue groups, not individual 2,3,7,8 congeners. Based on the findings reported by Inui et al. (2008), the uptake of congeners within a homologue group can vary and, therefore, the uptake reported for a homologue group cannot be applied to all congeners within that homologue group. For example, Inui et al. (2008) present uptake factors for three congeners within the TCDD homologue group. The uptake factors vary by more than 4-fold, with the lowest uptake factor reported for the 2,3,7,8-TCDD congener – the only congener assumed to be potentially toxic within that homologue group. Using an uptake factor reported for the TCDD homologue group, as opposed to uptake factors for each congener in the group, would overestimate the uptake of the 2,3,7,8-TCDD congener and the toxicity associated with the homologue group. In cases where the non-

[5] Inui, H., Wakai, T., Gion, K., Kim, Y-S., and Eun, H. 2008. Differential uptake for dioxin-like compounds by zucchini subspecies. Chemosphere, 73(10):1602-1607.

[6] Zhang, H., Chen, J., Ni, Y., Zhang, Q., Zhao, L. 2009. Uptake by roots and translocation to shoots of polychlorinated dibenzo-p-dioxins and dibenzofurans in typical crop plants. Chemosphere, 76(6):740-746.

2,3,7,8-chlorinated congeners have lower uptake rates than the 2,3,7,8-chlorinated congeners, use of the homologue group uptake rate could underestimate the dose of the congeners assumed to be potentially toxic. Due to this variability in uptake rate between individual congeners in a homologue group, the uptake rate associated with a homologue group should not be used for each of the congeners within that homologue group.

When conducting risk assessments, accounting for differential uptake of different 2,3,7,8 congeners is a well-recognized practice[7]. Because Inui et al. (2008) provide congener-specific uptake rates, their findings should be used instead of Hulster et al. (1994) to estimate potential concentrations of TCDD-TEQ in zucchini. **Table 1** shows the total TCDD-TEQ concentration predicted to be present in different zucchini cultivars assuming the congener concentrations reported for SS-55 and using the congener specific uptake rates obtained from Inui et al. (2008).

- Inui et al. (2008) highlight that uptake rates differ between cultivars of zucchini. Within that study, three cultivars were evaluated: Patty Green, Black Beauty, and Gold Rush. The TCDD-TEQ concentration accumulated in Black Beauty and Gold Rush was about 180 times higher than in Patty Green. Differential uptake by cultivar should be considered when estimating exposure as consumption is not likely to be limited to only one type of cultivar.

The results of Inui et al. (2008) can be used to predict TCDD-TEQ soil to zucchini uptake rates on a Site-specific basis for three different zucchini cultivars (using the congener distribution reported for off-site sampling location SS-55 near the former Koppers facility). As shown by the calculations reported in the first half of **Table 1**, those calculated TCDD-TEQ uptake rates vary by zucchini cultivar from 0.005% to 0.63% (Table 1). All of those rates are lower than the 1.35% reported in Hulster et al. (1994)[8]. Using these calculated Site-specific uptake rates results in threshold soil

[7] USEPA, 2005. Office of Solid Waste and Emergency Response. U.S. Environmental Protection Agency. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. September, 2005.

[8] The second half of **Table 1** presents homologue group uptake ratios for several soils included in Hulster et al. (1994) adjusted for the congener distribution at sampling location SS-55. As noted above, homologue-specific uptake rates are not appropriate to apply to congener concentrations, but Hulster et al. (1994) only report uptake ratios

concentrations that range from 454 ppt to 57,143 ppt (assuming the 0.7 g/kg-day ingestion rate used by FDOH)[9]. These threshold soil concentrations are 2.1-fold to 270-fold higher than the corrected FDOH threshold soil concentration of 212 ppt (see **Table 2**). All residential soils to the west of the Site are well below these adjusted threshold soil concentrations, again suggesting that no advisory for homegrown zucchini consumption is needed.

Intake (Consumption) Rate for Zucchini

Review of Consumption Rate Derivation

ARCADIS reviewed the intake rate assumptions used by FDOH to estimate the non-cancer TCDD-TEQ dose and the TCDD-TEQ threshold soil concentration. For reasons specified below, the selected intake rate of 0.7 g/kg-day is not representative of home-produced zucchini consumption. Alternate intake rates are presented below, as well as corresponding dose estimates and threshold soil concentrations.

Review of Intake Rate Derivation

The zucchini intake rate presented in the dHC (0.7 g/kg-day) was obtained from Table 9-6 of the 2011 EFH (USEPA, 2011) and is based on the mean consumer-only intake rate of all cucurbits. The selected intake rate represents the mean intake for all cucurbit consumption, including both home grown and commercially produced vegetables. Based on personal communication with the USEPA (Jacqueline Moya of USEPA with Danielle Pfeiffer of ARCADIS, September 12, 2013), the cucurbits category includes the vegetables and vegetable products (zucchini consumption was included as summer squash) shown below.

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for homologue groups. If the homologue group specific uptake rates are applied to the Site-specific congener distribution, the TCDD-TEQ uptake rates range from 0.25% to 1.04%. All of these uptake rates are lower than the 1.35% used by the dHC and Neighborhood Update and demonstrate why the TCDD-TEQ uptake rate of 1.35% reported by Hulster et al. (1994) cannot be applied directly to soils in the vicinity of the Former Koppers facility and why the Site-specific distribution of congeners must be accounted for when estimating uptake from soils.

[9] Inui et al. (2008) uptake rates are presented in wet weight and do not need to be converted prior to inclusion in the dose or threshold soil concentration calculations.

- Cantaloupe
- Honeydew Melons
- Watermelon juice
- Balsam pear
- Chayote fruit
- Chinese waxgourd
- Cucumber
- Pumpkin
- Pumpkin seed
- Summer squash
- Winter squash
- Summer squash (babyfood)
- Winter squash (babyfood)

By incorporating this intake rate into the zucchini exposure calculations, the FDOH assumes that 100% of a person's total zucchini intake is grown near the Site. In Chapter 13 of the 2011 EFH, USEPA's National Center for Environmental Assessment (NCEA) analyzed USDA's 1987–1988 Nationwide Food Consumption Survey (NFCS) to generate intake rates specifically for home-produced foods. The methods used to analyze the 1987–1988 NFCS data are presented in Section 13.3 of the 2011 EFH. Results of this home-produced food survey indicate (Table 13-68 of 2011 EFH) that only a small fraction of vegetable intake (less than 10 percent) is actually home-produced. As such, the FDOH intake rate is overly conservative and overestimates typical zucchini intake near the Site.

Section 2 of USEPA's *Example Exposure Scenarios* (USEPA, 2004)[10] document includes recommended approaches on how to incorporate EFH intake rates into home-produced vegetable consumption exposure equations. The following examples, based on methods outlined in USEPA 2004, provide alternate, more applicable, intake rates than the 0.7 g/kg-day value selected by FDOH.

- Alternate intake 1. As explained in the *Example Exposure Scenarios* document, the per capita intake rate for all homegrown vegetables can be estimated using the mean per capita ("as eaten") vegetable intake rate (2.9

[10] USEPA, 2004. National Center for Environmental Assessment. U.S. Environmental Protection Agency. Example Exposure Scenarios. April 2004. Accessed via http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=85843.

g/kg-day average of mean intake for whole population) from Table 9-3 of the EFH (USEPA, 2011) and multiplying that intake value by the fraction of total vegetable intake represented by homegrown vegetables (0.07) from Table 13-68 of the 2011 EFH. The resulting value represents the per capita intake rate of all homegrown vegetables (0.203 g/kg-day). This intake rate is approximately 3.5-fold lower than the zucchini intake rate used in the dHC dose calculations. If this homegrown vegetable intake rate was used along with the most conservative 0.63% zucchini uptake ratio from Inui et al. (2008), the resulting dose associated with a 70 ppt TCDD-TEQ soil concentration would be 9×10^{-11} mg/kg/day of TCDD-TEQ and the corresponding zucchini consumption threshold soil concentration would be 1,564 ppt (based on the NOAEL). This alternate non-cancer dose is more than two orders of magnitude below the lowest observed adverse effect level (LOAEL) of 2×10^{-8} mg/kg/day (USEPA 2013). These values, as well as several alternate dose and threshold soil concentrations are summarized in **Table 2**.

- Alternate intake 2. Although zucchini-specific intake rates are not available in the 2011 EFH or in the associated surveys, the home-produced cucurbit intake rate can be derived using the approach summarized in the prior bullet. Specifically, the home-produced cucurbit intake rate can be calculated by multiplying the mean per capita ("as eaten") cucurbit intake rate (0.34 g/kg-day) from Table 9-5 of the 2011 EFH (USEPA, 2011) by the fraction of total "exposed vegetable"[11] intake represented by homegrown vegetables (0.095) from Table 13-68 of the 2011 EFH. The resulting intake rate represents the per capita homegrown intake rate of cucurbits (0.03 g/kg-day). This intake rate is approximately 23-fold lower than the zucchini intake value used in the dHC dose calculations. If this value was used along with the most conservative 0.63% zucchini uptake ratio from the Inui et al. (2008) study (see **Table 1**), the resulting dose associated with a 70 ppt TCDD-TEQ soil concentration would be 1×10^{-11} mg/kg/day of TCDD-TEQ and the

[11] The cucurbit group is not shown in Table 13-68; therefore, the selected fraction is instead based on the value presented for "exposed vegetables". Table 13B-1 indicates that zucchini was reported in the "exposed vegetables" sub-category of the survey. This sub-category includes many other vegetables in addition to zucchini and cucurbits. Therefore, the use of this fraction likely overestimates the actual fraction of cucurbits or zucchini that are homegrown.

corresponding zucchini consumption threshold soil concentration would be 10,582 ppt (based on the NOAEL). This alternate non-cancer dose is more than three orders of magnitude below the LOAEL of 2 x 10^{-8} mg/kg/day (USEPA 2013). These values, as well as several alternate dose and threshold soil concentration calculations are summarized in **Table 2**.

- Alternative intake 3. Another alternate intake rate calculation approach is presented in the *Example Exposure Scenario* document using available "consumer only" data. The mean "consumer only" total vegetable homegrown intake rate (2.08 g/kg-day based on total presented for "All Regions") from Table 13-10 of the EFH (USEPA, 2011) is multiplied by the average percent of individuals in these groups consuming homegrown vegetables during the survey period (18.29%) from Table 13-10 to estimate the per capita homegrown vegetable intake rate. Also, because the intake data in Table 13-10 are based on household use data (i.e., raw; not "as eaten" as used in the above examples), they are multiplied by 1 minus the weight of the food item lost in preparation (12.4% as shown in Table 13-69) to arrive at the per capita "as eaten" homegrown vegetable intake rate. The resulting value [2.08 g/kg-day * 0.1829 * (1-0.124)] represents the per capita homegrown intake rate (0.33 g/kg-day). This intake rate for all vegetables is approximately 2.1-fold lower than the zucchini intake value used in the dHC dose calculations. If this value was used along with the most conservative 0.63% zucchini uptake ratio derived from Inui et al. (2008), the resulting dose for the 70 ppt off-Site TCDD-TEQ dioxin soil concentration (at SS-55) would be 1.5 x 10^{-10} mg/kg/day of TCDD-TEQ and the corresponding zucchini consumption threshold soil concentration would be 962 ppt (based on the NOAEL). This alternate non-cancer dose is more than two orders of magnitude below the LOAEL of 2 x 10^{-8} mg/kg/day (USEPA 2013). As noted in the *Example Exposure Scenario* document, this alternate calculation approach uses data from the household portion of the NFCS in which waste and spoilage are not considered in calculating intake rates. As such, the total vegetable intake rate is slightly higher than the total vegetable intake rate presented in the first bullet. This calculation, as well as the other alternate dose and threshold soil concentrations calculations are summarized in **Table 2**.

- Alternative intake 4. The selected zucchini intake rate presented in the dHC (0.7 g/kg-day) correlates to a serving size of 49 grams of zucchini per day for

an average individual. This is similar to the typical USDA serving size for summer squash (57 grams) (USDA, 2009)[12]. In Florida, zucchini have two growing seasons and can be grown for approximately 6 months of the year (Univ. of Florida, 2009[13]). Therefore, ingestion of homegrown zucchini within the areas near the Site can only occur for half of the year. If 57 grams of zucchini are consumed each day of the 6 months and no homegrown zucchini is consumed for the other 6 months, the resulting average daily serving size of homegrown zucchini for the entire year would be 29 grams per day (57 grams divided by 2). This serving size can be converted to an intake rate of 0.4 g/kg-day, a rate that is approximately 1.8-fold lower than the intake value used in the dHC. If this value of 0.4 g/kg-day was used along with the most conservative 0.63% zucchini uptake ratio derived from Inui et al. (2008), the resulting dose for the off-Site residential TCDD-TEQ dioxin soil concentration at SS-55 (70 ppt) would be 2×10^{-10} mg/kg/day of TCDD-TEQ and the corresponding zucchini consumption threshold soil concentration would be 766 ppt (based on the NOAEL). This alternate non-cancer dose is two orders of magnitude below the lowest observed adverse effect level (LOAEL) of 2×10^{-8} mg/kg/day (USEPA 2013). This calculation, as well as other alternate dose and threshold soil concentration calculations, are summarized in **Table 2**.

Uncertainty associated with Intake Rate Data

The intake data presented in the 2011 EFH (USEPA, 2011) and cited in the prior section of this letter (NHANES 2003-2006 and NFSC 1987-1988) are based on survey data collected over short periods (i.e., 2 to 7 days), but typically are used in dose equations to represent long-term averages. Extrapolating long-term exposures based on results of short recall period survey data presents several challenges.

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[12] USDA, 2009. United States Department of Agriculture. Household Commodity Fact Sheet (Summer Squash, fresh). April 2009. Accessed via http://www.fns.usda.gov/fdd/facts/hhpfacts/New_HHPFacts/Veges/HHFS_SUMMERSQUASH_F151_Final.pdf.

[13] Document is SP 103, one of a series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date December 1999. Revised December 2010. Reviewed February 2012.

These include the potential misclassification of non-consumers, the overestimation of potential risks based on data collected as a snapshot in time, and the lack of consideration of variation in consumption rate over time.

USEPA (2011) has acknowledged that short-term dietary records are problematic when attempting to estimate long-term rates of consumption, particularly for upper bound intake estimates. For example, in its review of NHANES 2003-2006 study data, USEPA (2011) stated, "The distributions generated from short-term and long-term data will differ to the extent that each individual's intake varies from day to day; the distributions will be similar to the extent that individuals' intakes are constant from day to day. Day-to-day variation in intake among individuals will be high for fruits and vegetables that are highly seasonal and for fruits and vegetables that are eaten year-round, but that are not typically eaten every day. For these fruits and vegetables, the intake distribution generated from short-term data will not be a good reflection of the long-term distribution". In addition, when discussing the methodology used for the NFCS study, USEPA (2011) stated that "The consumer-only data presented represent average daily intake rates of food items/groups over the 7-day survey period and do not account for variations in eating habits during the rest of the year".

Absence of Consumption Advisories at Other Dioxin Sites

A review of Department of Health files, USEPA notices, and available ATSDR publications did not reveal the issuance of any vegetable consumption advisories for other dioxin sites across the country, including sites where residential TCDD-TEQ soil concentrations are orders of magnitude greater than those detected near the former Koppers facility. In fact, the 2003 exposure assessment component of the USEPA Dioxin Reassessment did not include exposure through fruits and vegetables, as this exposure was considered to be insignificant (USEPA, 2003, Part 1, Volume II, Chapter 4[14]). The (2006[15]) NAS review of the PCDD/PCDF exposure

[14] USEPA, 2003. National Center for Environmental Assessment. U.S. Environmental Protection Agency. Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds: National Academy Sciences (NAS) Review Draft (Part 1, Volume II, Chapter 4). December 2003. Accessed via http://www.epa.gov/ncea/pdfs/dioxin/nas-review/pdfs/part1_vol2/dioxin_pt1_vol2_ch04_dec2003.pdf.

[15] NAS. 2006. Health risks from dioxin and related compounds: evaluation of the EPA reassessment. National Academies of Science, National Research Council, Committee

assessment did not find the need to revise the USEPA's conclusion on this potential exposure pathway. USEPA also conducted an analysis of consumption of homegrown vegetables as part of their risk evaluation for the biosolids rule and concluded that the ingestion of fruits and vegetables are minor contributors to potential exposure and risk. These findings mirror the corrected FDOH dose results (adjusting to a wet weight basis) and the alternate dose results that were calculated in prior sections of this letter. Furthermore, at this Site, maximum off-site soil concentrations of TCDD-TEQ are below the corrected Neighborhood Update TCDD-TEQ threshold soil concentration, as well as the more applicable threshold soil concentrations presented in this report (all based on the NOAEL used by FDOH in the dHC).

Conclusions

ARCADIS has reviewed the dioxin and furan in zucchini analysis presented in the dHC, as well as the August 2013 Neighborhood Update issued by the FDOH. The dHC concludes that the dose from eating zucchini grown in soil near the former Koppers facility with 70 ppt of TCDD-TEQ (sampling location S-55) would "likely be too high to rule out the possibility of non-cancer illness", while this zucchini exposure pathway could "result in a "low" increased cancer risk of 1×10^{-4}". In the Neighborhood Update, the FDOH recommends that residents near the Site limit consumption of zucchini grown in soil with tetrachlorodibenzo-p-dioxin toxicity equivalent (2,3,7,8-TCDD TEQ) concentrations greater than 23 parts per trillion (ppt).

A review of the calculations presented in the dHC and the Neighborhood Update indicates that - contrary to the conclusions of the dHC and the Neighborhood Update - the zucchini ingestion pathway is not associated with an unacceptable potential risk and that the advisory is not warranted. ARCADIS's review has identified at least the following bases for this conclusion:

- The calculations presented in the dHC and Neighborhood Update did not account for the soil to zucchini uptake ratio being based on dry weight and the ingestion rate on wet weight. When the FDOH-assumed uptake ratio for zucchini (taken from Hulster at al. (1994)) is converted to a wet weight value of 1.35%, the resulting ingestion dose is 6×10^{-10} mg/kg/day of TCDD-TEQ.

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on EPA's Exposure and Human Health Reassessment of TCDD and Related Compounds. Board on Environmental Studies and Toxicology, Division on Earth and Life Studies. The National Academies Press, Washington, D.C.

This dose is nearly two orders of magnitude below the LOAEL of 2 x 10^{-8} mg/kg/day (USEPA 2013) used by FDOH to evaluate the need for an advisory and results in a threshold soil concentration of 212 ppt TCDD-TEQ, not the 23 ppt reported in the Neighborhood Update. All residential soils to the west of the Site are well below this 212 ppt TCDD-TEQ concentration;

- The FDOH uptake rate (1.35% wet weight based on Hulster et al. (1994)) is not appropriate for soils in the neighborhood to the west of the Site. The source of the dioxins and furans in the Hulster et al. (1994) study (chloralkali residues) is different from the sources west of the Site. Homologue patterns, and likely other characteristics, differ between the soils used in Hulster et al. (1994) and soils to the west of the Site. In addition, Hulster et al. (1994) do not report uptake rates for individual 2,3,7,8 congeners (only homologue groups). Using studies that have evaluated zucchini uptake rates for individual dioxin congeners, an alternate conservative uptake rate of 0.63% was derived based on the congener-specific uptake data reported in Inui et al. (2008). When the Inui et al. (2008) uptake rate data are combined with the FDOH intake of 0.7 g/kg-day, the resulting threshold soil concentration from consumption of homegrown zucchini is 454 ppt TCDD-TEQ. All residential soils to the west of the Site are well below this 454 ppt TCDD-TEQ concentration; and

- The assumed FDOH zucchini intake rate (0.7 g/kg-day) is based on the consumption of all cucurbits (both home grown and commercially produced vegetables). For a number of reasons, this rate overestimates homegrown zucchini consumption. For example, only a small fraction of intake is actually home-produced, and in the subject geographic area, homegrown zucchini is only available for 6 months out of the year. A number of alternate, more reasonable, intake rates were calculated by ARCADIS and these alternate intake rates ranged from 0.03 to 0.4 g/kg-day. These rates correspond to threshold soil concentrations from consumption of homegrown zucchini ranging from 766 to 10,582 ppt TCDD-TEQ (based on the NOAEL). All residential soils to the west of the Site are well below these concentrations of TCDD-TEQ.

Based on the evaluations presented above, the advisory for consumption of zucchini in soils surrounding the former Koppers site is not needed. Moreover, this conclusion is supported by the absence of vegetable ingestion advisories for other dioxin sites across the country. ARCADIS recommends that FDOH and ATSDR rescind the warning issued to the public in the Neighborhood Update and, further,

that appropriate corrections be made to the calculations and information presented in the dHC on potential risk associated with homegrown zucchini consumption before that document is finalized.

Sincerely,

ARCADIS U.S., Inc.

Paul D. Anderson, PhD.
Vice President, Principal Scientist

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Figure 1
Comparison of Homolog Distribution
(Percent of Total Dioxin/Furan Concentration)

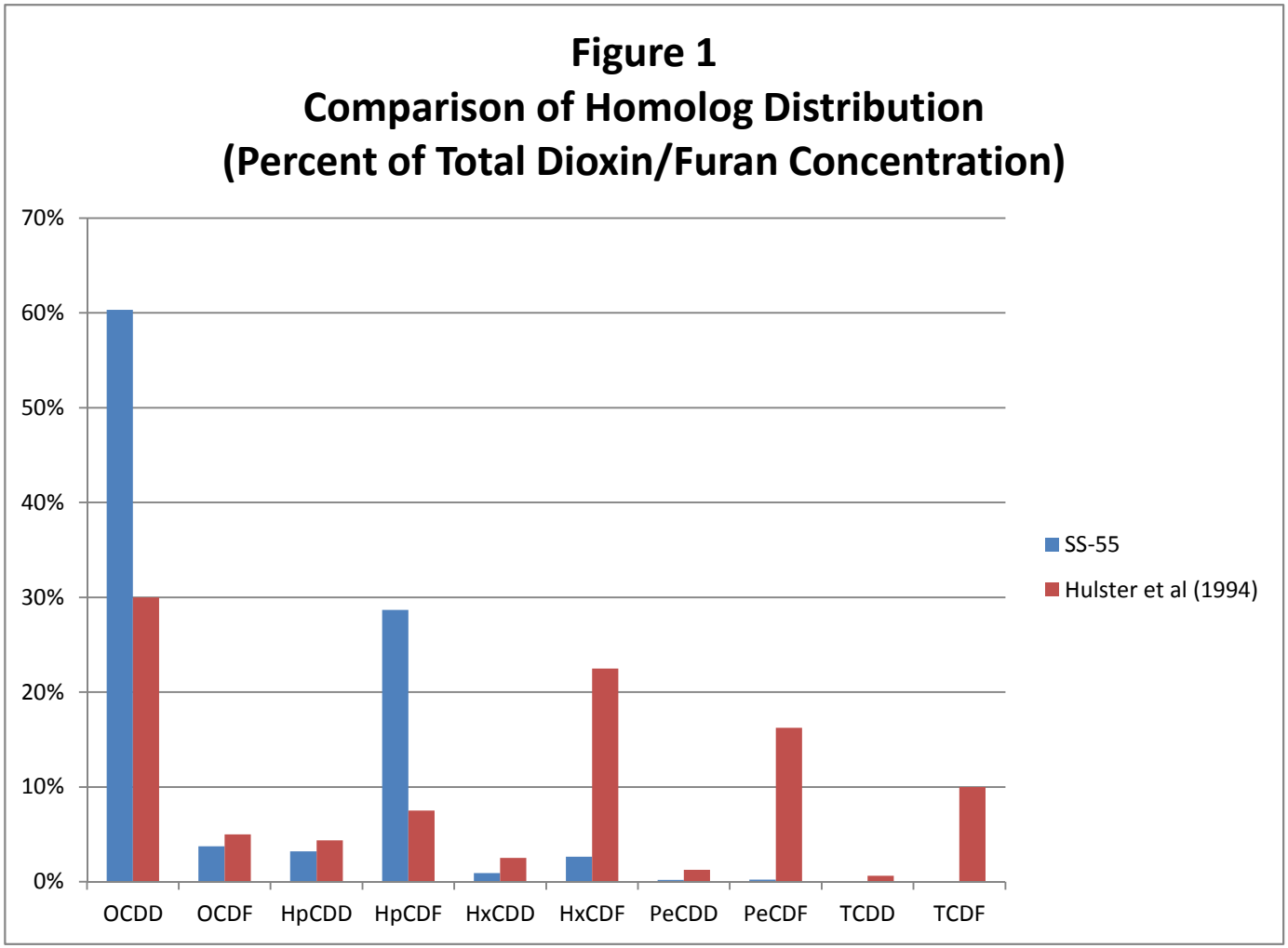

Table 1: Congener-specific Uptake Values and TCDD-TEQ Uptake Values

			Soil		Patty Green Zucchini (Inui et al., 2008)			Black Beauty Zucchini (Inui et al., 2008)			Gold Rush Zucchini (Inui et al., 2008)		
Sample ID	Congener	TEF	Soil Concentration (pg/g)	Soil TCDD TEQ (pg/g)	Patty Green BEF	Zucchini BEQ	Zucchini BTEQ	Black Beauty BEF	Zucchini BEQ	Zucchini BTEQ	Gold Rush BEF	Zucchini BEQ	Zucchini BTEQ
SS55AA	1,2,3,4,6,7,8-HpCDF	0.01	385	3.85	0.001%	3.13E-03	3.13E-05	0.20%	7.55E-01	7.55E-03	0.21%	8.15E-01	8.15E-03
SS55AA	1,2,3,4,6,7,8-HpCDD	0.01	2930	29.3	0.002%	5.17E-02	5.17E-04	0.21%	6.23E+00	6.23E-02	0.23%	6.83E+00	6.83E-02
SS55AA	1,2,3,4,7,8,9-HpCDF	0.01	24.4	0.244	0.001%	1.46E-04	1.46E-06	0.10%	2.39E-02	2.39E-04	0.10%	2.51E-02	2.51E-04
SS55AA	1,2,3,4,7,8-HxCDF	0.1	11.3	1.13	0.01%	6.31E-04	6.31E-05	0.64%	7.21E-02	7.21E-03	0.65%	7.31E-02	7.31E-03
SS55AA	1,2,3,4,7,8-HxCDD	0.1	31	3.1	0.003%	9.73E-04	9.73E-05	0.77%	2.40E-01	2.40E-02	0.79%	2.45E-01	2.45E-02
SS55AA	1,2,3,6,7,8-HxCDF	0.1	10.4	1.04	0.003%	2.98E-04	2.98E-05	0.63%	6.60E-02	6.60E-03	0.66%	6.86E-02	6.86E-03
SS55AA	1,2,3,6,7,8-HxCDD	0.1	69	6.9	0.01%	7.05E-03	7.05E-04	0.92%	6.34E-01	6.34E-02	0.95%	6.58E-01	6.58E-02
SS55AA	1,2,3,7,8,9-HxCDF	0.1	2.23	0.223	0.002%	3.41E-05	3.41E-06	0.23%	5.22E-03	5.22E-04	0.20%	4.51E-03	4.51E-04
SS55AA	1,2,3,7,8,9-HxCDD	0.1	44.5	4.45	0.01%	3.82E-03	3.82E-04	0.99%	4.40E-01	4.40E-02	0.99%	4.43E-01	4.43E-02
SS55AA	1,2,3,7,8-PeCDF	0.03	1.32	0.0396	0.01%	1.42E-04	4.27E-06	1.79%	2.36E-02	7.07E-04	1.93%	2.54E-02	7.62E-04
SS55AA	1,2,3,7,8-PeCDD	1	7.86	7.86	0.02%	1.20E-03	1.20E-03	2.12%	1.66E-01	1.66E-01	1.99%	1.56E-01	1.56E-01
SS55AA	2,3,4,6,7,8-HxCDF	0.1	18.9	1.89	0.002%	3.06E-04	3.06E-05	0.55%	1.04E-01	1.04E-02	0.56%	1.06E-01	1.06E-02
SS55AA	2,3,4,7,8-PeCDF	0.3	4.59	1.377	0.01%	2.92E-04	8.75E-05	1.52%	6.96E-02	2.09E-02	1.53%	7.01E-02	2.10E-02
SS55AA	2,3,7,8-TCDF	0.1	0.683	0.0683	0.04%	2.82E-04	2.82E-05	3.50%	2.39E-02	2.39E-03	4.47%	3.05E-02	3.05E-03
SS55AA	2,3,7,8-TCDD	1	0.514	0.514	0.04%	1.99E-04	1.99E-04	1.29%	6.65E-03	6.65E-03	1.49%	7.66E-03	7.66E-03
SS55AA	OCDF	0.0003	1500	0.45	0.0002%	2.85E-03	8.56E-07	0.02%	3.05E-01	9.16E-05	0.02%	3.21E-01	9.63E-05
SS55AA	OCDD	0.0003	24200	7.26	0.004%	9.45E-01	2.83E-04	0.23%	5.67E+01	1.70E-02	0.20%	4.77E+01	1.43E-02
				69.6959			3.67E-03			4.40E-01			4.40E-01
					TCDD TEQ Uptake=		0.005%	TCDD TEQ Uptake=		0.63%	TCDD TEQ Uptake=		0.63%

Notes

All BEFs reported on a wet weight basis. Hulster et al. (1994) values were adjusted from dry weight assuming 90% moisture
BEF = bioaccumulation equivalency factor
TEF = Toxicity equivalent factor (WHO, 2005)
Soil Concentrations presented in parts per trillion (ppt)
BEF (Inui et al., 2008) calculated from supplemental information for Figure 2.
BEQ = soil concentration x BEF (units of pg/g)
BTEQ = BEF x soil concentration x TEF (units of pg/g)
BEF (Hulster et al. (1994)) estimated from Figure 3, converted to wet weight
Rein. = Rheinfelden
Crail. = Crailsheim
1b = In Hulster et al. (1994), these vegetables were grown without contact with the soil
1a = In Hulster et al. (1994), these vegetables were grown with direct contact with the soil

References

Huelster, Anke, Mueller, Jochen F. and Marschner, Horst (1994) Soil-plant transfer of polychlorinated Dibenzo-p-dioxins and dibenzofurans to vegetables of the cucumber family (Cucurbitaceae). *ES&T*, *28* 6: 1110-1115.
Hideyuki Inui, Taketo Wakai, Keiko Gion, Yun-Seok Kim, and Heesoo E (2008) Differential uptake for dioxin-like compounds by zucchini subspecies. Chemosphere 73(10):6

Table 1: Congener-specific Uptake Values and TCDD-TEQ Uptake Values

			Soil		Rheinfelden 1b (Hulster et al., 1994)			Crailsheim: Cs = 328 (Hulster et al., 1994)			Rheinfelden 1a (Hulster et al., 1994)			Crailsheim: Cs = 2390 (Hulster et al., 1994)		
Sample ID	Congener	TEF	Soil Concentration (pg/g)	Soil TCDD TEQ (pg/g)	BEF (Rhein. 1b)	Zucchini BEQ	Zucchini BTEQ	BEF (Crail. 328)	Zucchini BEQ	Zucchini BTEQ	BEF (Rhein. 1a)	Zucchini BEQ	Zucchini BTEQ	BEF (Crail. 2390)	Zucchini BEQ	Zucchini BTEQ
SS55AA	1,2,3,4,6,7,8-HpCDF	0.01	385	3.85	0.5%	1.93E+00	1.93E-02	0.2%	7.70E-01	7.70E-03	0.5%	1.93E+00	1.93E-02	0.08%	3.08E-01	3.08E-03
SS55AA	1,2,3,4,6,7,8-HpCDD	0.01	2930	29.3	0.5%	1.47E+01	1.47E-01	0.2%	5.86E+00	5.86E-02	0.5%	1.47E+01	1.47E-01	0.08%	2.34E+00	2.34E-02
SS55AA	1,2,3,4,7,8,9-HpCDF	0.01	24.4	0.244	0.5%	1.22E-01	1.22E-03	0.2%	4.88E-02	4.88E-04	0.5%	1.22E-01	1.22E-03	0.08%	1.95E-02	1.95E-04
SS55AA	1,2,3,4,7,8-HxCDF	0.1	11.3	1.13	1.4%	1.58E-01	1.58E-02	0.5%	5.65E-02	5.65E-03	1.4%	1.58E-01	1.58E-02	0.20%	2.26E-02	2.26E-03
SS55AA	1,2,3,4,7,8-HxCDD	0.1	31	3.1	1.9%	5.89E-01	5.89E-02	0.6%	1.71E-01	1.71E-02	0.8%	2.48E-01	2.48E-02	0.20%	6.20E-02	6.20E-03
SS55AA	1,2,3,6,7,8-HxCDF	0.1	10.4	1.04	1.4%	1.46E-01	1.46E-02	0.5%	5.20E-02	5.20E-03	1.4%	1.46E-01	1.46E-02	0.20%	2.08E-02	2.08E-03
SS55AA	1,2,3,6,7,8-HxCDD	0.1	69	6.9	1.9%	1.31E+00	1.31E-01	0.6%	3.80E-01	3.80E-02	0.8%	5.52E-01	5.52E-02	0.20%	1.38E-01	1.38E-02
SS55AA	1,2,3,7,8,9-HxCDF	0.1	2.23	0.223	1.4%	3.12E-02	3.12E-03	0.5%	1.12E-02	1.12E-03	1.4%	3.12E-02	3.12E-03	0.20%	4.46E-03	4.46E-04
SS55AA	1,2,3,7,8,9-HxCDD	0.1	44.5	4.45	1.9%	8.46E-01	8.46E-02	0.6%	2.45E-01	2.45E-02	0.8%	3.56E-01	3.56E-02	0.20%	8.90E-02	8.90E-03
SS55AA	1,2,3,7,8-PeCDF	0.03	1.32	0.0396	1.7%	2.24E-02	6.73E-04	1.2%	1.52E-02	4.55E-04	1.4%	1.85E-02	5.54E-04	0.65%	8.58E-03	2.57E-04
SS55AA	1,2,3,7,8-PeCDD	1	7.86	7.86	2.2%	1.73E-01	1.73E-01	1.0%	7.86E-02	7.86E-02	2.9%	2.28E-01	2.28E-01	1.20%	9.43E-02	9.43E-02
SS55AA	2,3,4,6,7,8-HxCDF	0.1	18.9	1.89	1.4%	2.65E-01	2.65E-02	0.5%	9.45E-02	9.45E-03	0.8%	1.51E-01	1.51E-02	0.20%	3.78E-02	3.78E-03
SS55AA	2,3,4,7,8-PeCDF	0.3	4.59	1.377	1.7%	7.80E-02	2.34E-02	1.2%	5.28E-02	1.58E-02	1.4%	6.43E-02	1.93E-02	0.65%	2.98E-02	8.95E-03
SS55AA	2,3,7,8-TCDF	0.1	0.683	0.0683	1.7%	1.16E-02	1.16E-03	1.0%	6.83E-03	6.83E-04	1.4%	9.56E-03	9.56E-04	0.65%	4.44E-03	4.44E-04
SS55AA	2,3,7,8-TCDD	1	0.514	0.514	2.7%	1.39E-02	1.39E-02	0.8%	4.11E-03	4.11E-03	1.8%	9.25E-03	9.25E-03	0.80%	4.11E-03	4.11E-03
SS55AA	OCDF	0.0003	1500	0.45	0.3%	3.75E+00	1.13E-03	0.1%	1.50E+00	4.50E-04	0.3%	3.75E+00	1.13E-03	0.01%	7.50E-02	2.25E-05
SS55AA	OCDD	0.0003	24200	7.26	0.1%	2.42E+01	7.26E-03	0.01%	1.21E+00	3.63E-04	0.1%	2.42E+01	7.26E-03	0.01%	1.21E+00	3.63E-04
				69.6959			7.22E-01			2.68E-01			5.98E-01			1.73E-01
					TCDD TEQ Uptake=		1.04%	TCDD TEQ Uptake=		0.38%	TCDD TEQ Uptake=		0.86%	TCDD TEQ Uptake=		0.25%

Notes

All BEFs reported on a wet weight basis. Hulster et al. (1994) values were adjusted from dry weight assuming 90% moisture
BEF = bioaccumulation equivalency factor
TEF = Toxicity equivalent factor (WHO, 2005)
Soil Concentrations presented in parts per trillion (ppt)
BEF (Inui et al., 2008) calculated from supplemental information for Figure 2.
BEQ = soil concentration x BEF (units of pg/g)
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References

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Hideyuki Inui, Taketo Wakai, Keiko Gion, Yun-Seok Kim, and Heesoo E (2008) Differential uptake for dioxin-like compounds by zucchini subspecies. Chemosphere 73(10):6

Table 2: Summary of Alternate Zucchini Threshold Values

	Uptake (Soil to Zucchini)*	Zucchini Consumption Rate	Non-cancer Dose**	Soil Threshold for Zucchini Exposure (based on NOAEL)
	Percent (ww)	g/kg-day (ww)	mg/kg-day	ng/kg
Draft Health Consultation (corrected)	1.35%	0.7	6.6E-10	212
Inui (2008) Uptake with with dHC Intake[1]	0.005%	0.7	2.5E-12	57,143
Inui (2008) Uptake with with dHC Intake[2]	0.63%	0.7	3.1E-10	454
Inui (2008) Uptake with Alternate Intake #1	0.63%	0.203	9.0E-11	1,564
Inui (2008) Uptake with Alternate Intake #2	0.63%	0.03	1.3E-11	10,582
Inui (2008) Uptake with Alternate Intake #3	0.63%	0.33	1.5E-10	962
Inui (2008) Uptake with Alternate Intake #4	0.63%	0.41	1.8E-10	766

Notes:

dHC = draft Health Consultation

NOAEL = No observed adverse effect level (2E-09 mg/kg-day)

*value of 1.35% is based on Hulster et al (1994) and value of 0.63% was derived using congener-specific uptake values (See Table 1 for derivation)

**Dose based on an assumed soil concentration of 70 ppt

1. Based on Patty Green Cultivar
2. Based on Black Beauty and Gold Rush Cultivars

References:

Hideyuki Inui, Taketo Wakai, Keiko Gion, Yun-Seok Kim, and Heesoo E (2008) Differential uptake for dioxin-like compounds by zucchini subspecies. Chemosphere 73(10):6

Huelster, Anke, Mueller, Jochen F. and Marschner, Horst (1994) Soil-plant transfer of polychlorinated Dibenzo-p-dioxins and dibenzofurans to vegetables of the cucumber family (Cucurbitaceae). *ES&T*, *28* 6: 1110-1115.