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SUBJECT: HEALTH-PROTECTIVE ESTIMATES OF SEASONAL AND ANNUAL REENTRY EXPOSURE TO ENDOSULFAN: TYPICAL REENTRY DAYS

During the Scientific Review Panel (SRP) evaluation of the revised final draft exposure assessment document (EAD) for endosulfan, a question arose about whether seasonal and annual exposures estimated by the California Department of Pesticide Regulation (DPR) are health-protective. Specifically, for seasonal and annual reentry exposure estimates, DPR assumes that on average reentry into a treated crop occurs approximately a week to 10 days later than the earliest allowed reentry following a pesticide application. This "typical reentry day" was generally determined by DPR from available information about reentry into pesticide-treated crops. Because pesticide residues on treated foliage decrease with time, exposure estimates for reentry 7 to 10 days later would typically be less than values based on the earliest possible reentry day. The question from the SRP was whether the lower estimates are sufficiently health-protective.

The question raised by the SRP is an important one as the DPR regulatory mandate is to ensure that pesticides are used in a health protective manner. For this reason, it is critical that exposures not be underestimated and therefore are health-protective. Conversely, exposure estimates should not be unrealistically high, as unrealistic estimates waste critical resources by developing unnecessary mitigation strategies. To this end, DPR approaches single and multiple exposure scenarios somewhat differently. For single, or short-term exposures, DPR attempts to determine the highest potential exposure that may result from legal activity. Thus for short-term exposure estimates for reentry workers, DPR assumes that reentry occurs at the earliest legal opportunity. Under California regulation, the restricted entry interval (REI) is 2 days for all activities in all crops treated with endosulfan (Title 3, California Code of Regulations, Section 6772). Preharvest intervals (PHIs) for crops treated with endosulfan range from 0 to 21 days; as food crops harvested during the PHI cannot legally be sold, DPR assumes that in the short term harvesting occurs promptly at the expiration of the PHI (if the PHI is longer than the REI).

For multiple exposure scenarios such as you might expect from seasonal or annual activities, DPR assumes that an individual is unlikely to encounter the highest potential exposure for each day they are exposed. That is, with field entry over a given season, workers are not likely to consistently reenter at the earliest legal opportunity following pesticide applications. Consistent reentry as soon as the REI (or the PHI) expires is not feasible because any pesticide is applied a finite number of times during the interval when reentry activities are likely to occur in each crop, and for most pesticides, there simply are not enough applications for each reentry to always immediately follow one. For example, if applications in a field occur every two weeks, then during daily work in that field the workers would enter first at the expiration of the REI, then one day after the REI expires (REI + 1), then REI +2, and so on until the next application occurs two weeks later. For an REI of 2 days, REI + 1 is 3 days post-application, and in this example reentry the day before the following application is REI + 11 (13 days post-application). Depending on how quickly the pesticide residues dissipate from the treated crop, the exposure on REI + 11 could be substantially less than at the expiration of the REI, and assuming consistent reentry at the expiration of the REI would result in unrealistically high exposure estimates.

As a way to avoid unrealistically high estimates, the logic supporting an assumed typical reentry day is fairly straightforward. What is needed next is support for specific reentry days that are realistic yet health protective. Is it health-protective to assume, as DPR does, that reentry typically occurs a week to 10 days following the expiration of the REI or PHI? To answer that question, ideally we would like to have observations of workers performing all usual activities in all crops, to provide data on when workers do specific tasks (and how close their reentry each day is to a pesticide application). Unfortunately, limited information is available on activity patterns of individual workers. Existing data consist of reported pesticide applications to crops and general descriptions of activities required to grow and harvest various crops.

However, the available data can be combined with certain assumptions to provide support that the typical reentry days assumed by DPR are appropriate and will lead to health-protective exposure estimates. Two key assumptions I am using to consider this are listed below:

- Throughout the seasonal and annual exposure intervals, workers are assumed to work daily (5 to 7 days per week), and only in crops treated with endosulfan.
- After each application workers enter as soon as possible (at the expiration of the REI or PHI), then enter on following days as close to the application as possible.

Harvest and cultivation activities such as thinning, weeding, irrigating, etc., are performed by work crews that can work in multiple fields. On the other hand, scouting is done by trained individuals. As different assumptions are needed for individuals than for

work crews, in this memo scouting scenarios are considered separately from harvesting and other reentry scenarios. The two key assumptions listed above are applied to all scenarios; additional assumptions are specified in the following sections.

Harvesting and Cultivation Activities

Data used to support typical reentry days assumed for harvesting and cultivation activities include crop profiles published by the University of California and reports of endosulfan applications in DPR's Pesticide Use Report (PUR) database. Crop profiles provide summaries of how crops are planted, cultivated, and harvested, and give typical parameters for field size, spacing of a crop within a field, and brief descriptions of fieldworker tasks, often including typical work crew sizes. Additionally, crop profiles provide estimates of typical labor costs to cultivate and harvest a crop. In a report estimating numbers of migrant and seasonal farmworkers in California, such estimates were used, along with data reported by the U.S. Department of Agriculture National Agricultural Statistics Service, to calculate hours per acre needed for hand labor within each crop (Larson, 2000).

The PUR summarizes agricultural applications of pesticides in California (non-agricultural applications made by licensed applicators are also reported in the PUR, but all endosulfan uses are agricultural). The PUR database was queried to find acres of each crop treated with endosulfan, as well as dates when endosulfan applications occurred.

Hand labor rates from Larson (2000) and typical crew sizes from crop profiles were combined with PUR data to develop estimates of typical reentry days following endosulfan applications. In addition to the two key assumptions stated previously, the following two additional assumptions were made:

- Each work crew is assumed to be equally likely to encounter endosulfan-treated fields or orchards.
- Endosulfan applications to each crop are assumed to be evenly spaced throughout the interval during which high endosulfan use overlaps the reentry activity of interest.

These assumptions allow an average number of applications encountered by each work crew to be calculated, from which the typical reentry day is estimated. Calculations and their results are summarized below in three tables.

Table 1 summarizes PUR data for endosulfan use on the crops with seasonal and annual harvesting and cultivation scenarios. By querying the PUR database for total annual use in each county, the counties with the highest endosulfan use on crops of interest were determined. Within each county, the high-use intervals overlapping the activities were

then determined; exposure to reentry workers is considered most likely during these intervals. In the EAD, the 5-year interval used was 2000 – 2004, and Table 1 reports results for the more recent interval of 2001 – 2005 (for crops in Table 1, the same counties and high-use intervals resulted from both intervals). Numbers of applications and acres treated with endosulfan are also summarized in Table 1. Examination of Table 1 shows that in each crop there were 10 or fewer days with endosulfan applications in the high-use interval that overlapped each activity.

Table 1. Endosulfan Use on Selected Crops During High-Use Intervals in 2001 - 2005

Crop	High-Use County or County Group [a]	High-Use Interval Overlapping Activity [b]	Number of Days with Applications [c]	Acres Treated [d]
Broccoli	Fresno	October – November	7	1,063
Sweet Corn	Fresno	June	3	416
Cucumber	Colusa	August – September	5	139
Grapes	Kern + Kings + Tulare	April – July	10	1,056
Peaches	Los Angeles	April – May; July	4	189
Tomatoes	Fresno	June – September	5	434

[a] Adjacent high-use counties were considered together, on the assumption that workers could move between them.
[b] Interval used to estimate seasonal and annual exposures for exposure assessment: Months in recent 5-year interval (2000 – 2004) when acres treated exceeded 5% of annual total, and when reentry activity of interest occurs. Note that the same county and interval result from the 5-year interval 2001 – 2005.
[c] Number of days with endosulfan applications in county or county group, averaged over 2001 – 2005 (DPR 2007; query run on multiple days between November 20, 2007 and November 27, 2007).
[d] Total number of acres treated with endosulfan in county or county group, averaged over 2001 – 2005 (DPR 2007; query run on multiple days between November 20, 2007 and November 27, 2007).

Table 2 summarizes calculations resulting in estimated numbers of workers in endosulfan-treated acres. The first column in Table 2 contains hand labor work rates estimated by Larson (2000). The second column in Table 2 summarizes the number of worker-days in treated acres, calculated by first dividing work rates (from the first column) by 8, to normalize them to an 8-hour workday, and multiplying the result by the average number of acres treated from Table 1. The number of days when workers are likely to be performing an activity (from the high-use months reported in the EAD and an assumption of 20 work days per month) are also summarized in Table 2, which when combined with the total number of worker-days in treated acres, gives the total number of workers needed to perform each activity in the treated area ("Workers in Treated Acres").

Table 2. Estimated Number of Workers That Harvest or Perform Other Cultivation Activities in Each Endosulfan-Treated Acre

Exposure Scenario	Hand Labor Work Rate (hours/acre) [a]	Worker-Days in Treated Acres [b]	Exposure Interval (months) [c]	Work Days in Interval [d]	Workers in Treated Acres [e]
Broccoli, Hand Harvesting	98	13,000	2	40	325
Sweet Corn, Hand Harvesting	37	1,920	1	20	96
Cucumbers, Hand Harvesting	110	1,910	2	40	48
Grapes, Cane Turning	174	23,000	4	80	288
Peaches, Thinning	117	2,760	3	60	46
Tomatoes, Hand Harvesting	318	17,252	4	80	216

[a] Estimates from Larson (2000).
[b] Calculated by dividing hours/acre in previous column by 8, assuming 8-hour workdays, and multiplying by treated acres from Table 1. Results rounded to 3 significant figures.
[c] From exposure assessment document.
[d] Calculated by assuming 20 workdays per month.
[e] Calculated by dividing value in second column ("Worker-Days in Treated Acres") by value in fourth column ("Work Days in Interval"). Results rounded up to the nearest whole number.

Table 3 summarizes the estimates of typical reentry days. Estimates of typical crew sizes are summarized in the first column in Table 3. The number of work crews in treated acres is calculated by dividing "Workers in Treated Acres" from Table 2 by the crew size; results are listed in the second column of Table 3. Assuming that each crew has an equal chance of encountering endosulfan-treated crops, the number of application days encountered by each crew was calculated by dividing "Work Crews in Treated Areas" in Table 3 by the number of days with applications in Table 1.

Finally, assuming that following each application a crew enters a field as early as possible and on subsequent days as close to the application as possible, the "Work Days in Interval" from Table 2 is divided by the number of application days per work crew to get the range of days following each application a crew would reenter. The result is divided by 2 to get the mid-point of the range, which is rounded up to nearest whole number and reported in Table 3 as the "Estimated Typical Reentry." For ease of comparison with the reentry days reported in the EAD, in Table 3 the number of days post-application is reported. If desired, the REI or PHI can be subtracted from the midpoint and the typical day reported as additional days beyond the REI or PHI. For example, the PHI for broccoli is 7 days, and the midpoint of the range of reentry is 29 days, or PHI + 22 days.

The EAD assumed an average reentry of 10 days post-application for all scenarios but broccoli hand harvesting, which assumed (because of the 7-day PHI) a typical reentry of

14 days post-application. As all scenarios in Table 3 had estimated typical reentry days greater than 10 (and greater than 14 for broccoli hand harvesting), the assumed typical reentry day is anticipated to lead to health-protective exposure estimates for each scenario.

Table 3. Estimated Numbers of Days with Endosulfan Applications Overlapping Work Days for Harvesters and Other Non-Scouting Reentry Workers

Exposure scenario	Size of Typical Work Crew [a]	Work Crews in Treated Areas [b]	Application Days per Crew [c]	Estimated Typical Reentry (Days) [d]
Broccoli, Hand Harvesting	30	10.8	0.68	29
Sweet Corn, Hand Harvesting	25	3.8	0.79	13
Cucumbers, Hand Harvesting	14	3.4	1.48	14
Grapes, Cane Turning	20	14.4	0.69	58
Peaches, Thinning	10	4.6	0.87	35
Tomatoes, Hand Harvesting	40	5.4	0.93	43

[a] Crew size estimates are from the following sources: broccoli (ALRB, 1984); sweet corn (Meister, 2004b); cucumber harvesting crew size assumed to be the same as for cantaloupe, reported by Mayberry (2000a); grapes (O'Connell *et al*., 1993); peach harvesting crew size assumed to be the same as for pears, reported by (Ingels *et al*., 2003); tomatoes (Stoddard *et al*., 2007).
[b] Calculating by dividing number of "Workers in Treated Acres" from Table 2 by number of workers in a crew (in first column).
[c] Calculated by dividing the "Number of Days with Applications" from Table 1 by the value in the second column.
[d] Days post-application. Calculated by dividing "Work Days in Interval" from Table 2 by "Application Days per Crew" to get the range of days following each application a crew would reenter, then dividing by 2 to get the mid-point of range, rounded up to nearest whole number.

Scouting Scenarios

Scouting is performed by individuals, rather than by work crews, and the number of workers needed to scout treated acres cannot be estimated as was done for work crews in other reentry scenarios. For this reason, different data and assumptions were used to support typical reentry days assumed for scouting. Data include the length of growing seasons from crop profiles, numbers of applications allowed to each crop from endosulfan product labels, and information obtained during a recent observational study of scouting activity patterns conducted by DPR.

Table 4 summarizes crop characteristics related to scouting in crops with seasonal and annual exposure scenarios in the endosulfan EAD, along with details about endosulfan applications in those crops. Growing seasons also vary by crop variety and location; the shortest season for each crop is reported in Table 4. The growing seasons reported for

crops in Table 4 suggest that in each year more than one crop can be planted and harvested in a single field.

Table 4. Estimated Typical Reentry Days for Scouting in Crops Treated with Endosulfan

Crop	Length of Growing Season (months) [a]	Scouting Frequency per week (total days) [b]	Number of Endosulfan Applications Allowed [c]	Application Interval (weeks) [d]	Reentry Pattern First Week Post-Application [e]	Estimated Typical Reentry per Crop (Days) [f]
Broccoli	3	2	2 per year	6	REI, + 3	REI + 19
Cotton	7	1	2 per season	14	REI	REI + 42
Lettuce	3	4	3 per season	4	REI, + 2, +4, +6	REI + 14
Potatoes	4	1	4 per season	4	REI	REI + 10

[a] From University of California Extension crop profiles: broccoli, lettuce, and potatoes grown in Imperial County (Mayberry, 2000b; Meister, 2004a; Meister, 2004c; Meister, 2004d) and cotton grown in San Joaquin Valley (Hutmacher *et al*., 2003). For crops with varying growing seasons, shortest was used.
[b] Number of times each week the same field might be scouted, based on Spencer *et al*. (2006) and Spencer (2007). Each field assumed scouted by a single individual throughout the growing season.
[c] Maximum number allowed on crop, on any product label (fewer might be allowed on some labels).
[d] Number of weeks between endosulfan applications in a single crop, calculated by dividing maximum allowed applications (third column) by length of growing season (column 1), assuming 4 weeks per month. For broccoli, one crop is assumed per year (i.e., that both applications are made to one crop).
[e] Assumed pattern of scouting in first week. For second week, add 7 to each day in first week, etc. For example, scouting twice a week is assumed to occur at the expiration of the REI and three days later (REI + 3) during first week, then REI + 7 and REI + 10 during second week, etc.
[f] Estimated by assuming that reentry pattern for the first week post-application (sixth column) is carried through the weeks in the estimated application interval (fifth column). The midpoint of the interval is used; if midpoint falls between two days in the pattern, the median value of the two days is used (e.g., for broccoli, midpoint is between REI + 17 and REI + 21).

To estimate a typical reentry day that is health-protective, in this memo three assumptions are needed in addition to the two key assumptions previously stated:

- It is assumed that scouting during a full growing season in each field is done by a single individual. This assumption is consistent with how DPR approaches scouting scenarios, assuming that scouts spend 8-hour days in contact with treated foliage.
- Scouting of a field is assumed to occur with the highest frequency reported for that crop, and this frequency (number of times a field is scouted per week) is assumed to persist throughout the growing season.
- Endosulfan applications to each field are assumed to be evenly spaced throughout the growing season, and a field is assumed to receive the maximum number of endosulfan applications allowed per growing season as specified on product labels.

A recent observational study conducted by DPR of scouting activity patterns suggests that scouting can involve frequent entry into fields (Spencer, 2003; Spencer *et al*., 2006). Spencer (2003) and Spencer *et al.* (2006) reported on scouting activities in several crops and counties; follow-up questions on crops listed in Table 4 were answered by Spencer (2007). Typical scouting intervals for each crop are listed in the second column of Table 4, based on estimates obtained in interviews that took place during the scouting observations. Most row and field crops are generally inspected weekly or biweekly (Spencer, 2003); scouting in lettuce occurs more frequently (Spencer, 2007). Scouting intervals vary throughout the growing season in most crops; in Table 4, the most frequent scouting intervals are reported and assumed to apply throughout the growing season. Interviews with scouts also addressed the question of whether they tend to enter fields before the REI has expired; such early reentry is relatively rare (Spencer *et al*., 2006). In this memo, reentry is assumed to typically occur starting at the expiration of the REI (labeled "REI" in Table 4), then on subsequent days as described below.

Limited numbers of endosulfan applications are allowed on each crop, and the maximum numbers of allowed applications are reported in the third column of Table 4. Assuming that applications are evenly spaced throughout the growing season, the application interval is reported in the fifth column. Scouting intervals and application intervals were combined to give a reentry pattern for each crop, summarized in the sixth column of Table 4. For example, during the 4-week application interval for potatoes reentry is assumed to occur at the expiration of the REI, REI + 7, REI + 14, and REI + 21. The midpoint of the interval would be REI + 10 (rounded from [7+14]/2 = 10.5).

Typical reentry days in Table 4 suggest that the typical reentry day of REI + 10 used in the EAD is health-protective for scouts.

Appraisal of Estimated Typical Reentry Days

To the extent that the assumptions documented in this memo are valid, the assumption of a typical reentry day of REI + 10 or PHI + 10 will give health-protective exposure estimates. Crop profiles suggest that most reentry activities, including weeding, thinning, irrigation, and harvesting, are not activities that must occur immediately following pesticide applications. Cultivation activities such as irrigation occur several times over a growing season, far more often than the allowed number of endosulfan applications in many crops. Harvesting also is unlikely to be close to endosulfan applications in cases where endosulfan use is limited to early in the growing season or following harvest. The assumption that work crews are equally likely to encounter endosulfan applications, and the calculation of average number of application days per work crew, are reasonable but also might oversimplify what crews actually encounter. While it is not anticipated that any work crew (or any worker) would encounter all endosulfan applications in a single

county in a growing season, the number of applications encountered could be underestimated by a simple average.

Licensed Pest Control Advisors (PCAs) and unlicensed scouts were observed in the DPR study; twenty PCAs and ten scouts were each observed for a full workday. Most of these individuals scouted in multiple fields, and sometimes in multiple crops; on average, they had fewer than 2 hours of foliar contact and scouted about a dozen fields during the workday (Spencer *et al*., 2006). Based on these observations, most scouts are actually exposed to limited amounts of foliage treated with various pesticides at differing intervals, and it is unlikely that a scout is exposed to endosulfan throughout a full workday, much less over a season. However, to estimate seasonal and annual exposure scouts are assumed to be in contact with treated foliage throughout each workday in the season. Furthermore, estimates for scouting scenarios are health-protective, because scouts are likely to perform activities unrelated to endosulfan applications, such as assessing the maturity of the crop and its nutrient status, checking for fungal infections, weeds, and insects (i.e., whether applications of fungicides, herbicides, or insecticides are warranted). In contrast, the EAD assumes that scouting scenarios only involve checking the effectiveness of a recent endosulfan application.

Other assumptions made by DPR contribute to health-protective estimates of seasonal and annual exposure. For example, all exposure estimates assume a pesticide is applied at the maximum application rate. However, many applications are not at the maximum allowed rate. To give an example involving endosulfan, the maximum application rate for endosulfan on tomato is one pound active ingredient (AI) per acre (1 lb AI/acre). For applications reported for Fresno County in 2005, rates calculated from reported pounds applied and acres treated were as low as 0.38 lb AI/acre, and averaged 0.82 lb AI/acre (DPR, 2007; queried November 26, 2007).

Conclusion

This memo provides support for typical reentry days assumed by DPR for seasonal and annual reentry exposures. Assuming a typical reentry day of PHI + 10 is appropriate and will give health-protective exposure estimates for harvesters in crops treated with endosulfan, and assuming a typical reentry day of REI + 10 results in health-protective estimates for other reentry scenarios.

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