Department of Pesticide Regulation

Brian R. Leahy
Director

M E M O R A N D U M

Edmund G. Brown Jr.
Governor

TO: Michel Oriel **HSM-17003**
Senior Environmental Scientist (Supervisory)
Worker Health and Safety Branch
(916) 324-8845

FROM: Pam Driggers *(original signed by P. Driggers)*
Research Scientist II
Worker Health and Safety Branch
(916) 445-6101

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SUBJECT: CASES REPORTED TO THE PESTICIDE ILLNESS SURVEILLANCE PROGRAM AND EVALUATED AS ASSOCIATED WITH EXPOSURE TO CHLORPYRIFOS, ALONE OR IN COMBINATION WITH OTHER PRODUCTS, 2004-2014

Background

Chlorpyrifos is an organophosphate insecticide whose mechanism of action is the inhibition of acetylcholinesterase (AChE), leading to build up of acetylcholine (Ach) in the body. This affects the central nervous system by blocking the enzyme cholinesterase that controls messages between nerve cells. Ach is vital to the human central and peripheral nervous systems, including "…contraction of skeletal muscles, regulation of heart and respiratory rates, stimulation of gastrointestinal motility…"[1]

An individual(s) can be exposed to chlorpyrifos through dermal, inhalation, oral and ocular routes. The signs of chlorpyrifos exposure are tearing eyes, runny nose, increased salivation and sweating, nausea, dizziness and headache. Signs of progression include muscle twitching, weakness or tremors, lack of coordination, vomiting, abdominal cramps, diarrhea, and pupil constriction with blurred or darkened vision. Severe toxicity causes increased heart rate, loss of consciousness, convulsions, respiratory depression and paralysis.

Chlorpyrifos has been used since 1965 on crops, turf, greenhouses and homes, and is one of the most frequently used organophosphate pesticides. It is available in various formulations including liquid, granular, and flowable concentrate and can be applied by either ground or aerial equipment. Chlorpyrifos can be used both alone and in combination with other products. Chlorpyrifos has a "skunky" odor, described sometimes as rotten eggs or garlic. The continued use of this product is currently under discussion by Federal and State regulatory agencies.

[1] Report to the Legislature: California's Cholinesterase Test Results Reporting and Medical Supervision Program, December 2015.

Animal studies conducted in the 1980s and 1990s revealed that low doses of this organophosphate pesticide were toxic to neurological development. These results caused intense public-consumer concern about the effects of chlorpyrifos on child development. In June of 2000, chlorpyrifos manufacturers reached an agreement with the United States Environmental Protection Agency (US EPA) to stop the use of this pesticide for indoor use.

Earlier studies indicating neurodevelopmental effects of chlorpyrifos in animals, prompted epidemiology studies of children exposed to chlorpyrifos in utero. Findings from these studies suggested that cognitive functioning in these children was impaired. In 2012, the US EPA issued a new label that lowered application rates, and created buffer zones around public places, recreational areas and homes in order to mitigate exposure to community members. In July 2015, chlorpyrifos was designated as a California Restricted Material because of concerns about human health and the chemical in surface water.

California Pesticide Illness Surveillance Program

The California Pesticide Illness Surveillance Program (PISP) maintains a database of pesticide-related cases. An associated case is a record of one pesticide exposure and its apparent effects evaluated as definitely, probably or possibly related to an exposure. A definite relationship indicates that both physical and medical evidence document exposure and consequent health effects. A probable relationship indicates that limited or circumstantial evidence supports a relationship to pesticide exposure. A possible relationship indicates that health effects correspond generally to the reported exposure, but evidence is not available to support a stronger relationship.

A **case** refers to a record of a pesticide exposure. An **episode** is an incident in which one or more people are exposed to the same source. PISP receives reports of pesticide exposure from the California Pesticide Control System (CPCS), California Worker's Compensation, and from healthcare providers. PISP staff screen these reports and send the ones that meet program criteria to the County Agricultural Commissioners (CACs) for investigation. The CACs investigate the reports to determine if any violations of pesticide laws and regulations have occurred, and collect information on the circumstances of exposure. The CACs send their reports to PISP for evaluation. PISP defines **agricultural** as pesticide use intended to contribute to production of an agricultural commodity, including livestock; and all other uses are considered **non-agricultural**. PISP defines **occupational** as an individual (who) was on the job at the time of the incident, and **non-occupational** as an individual (who) was not on the job at the time of the incident.

Methods

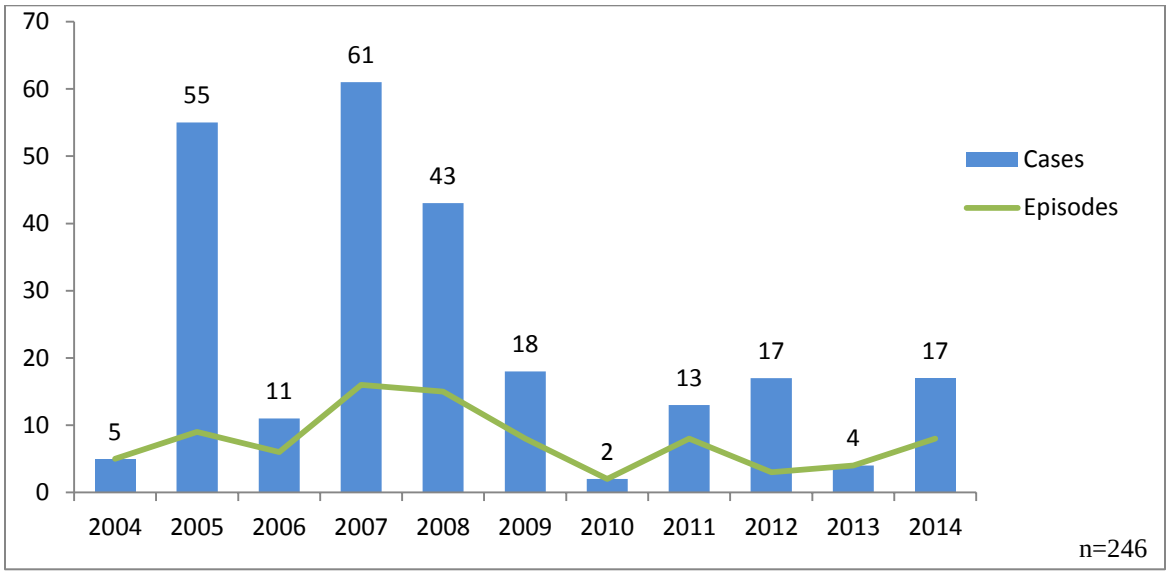
A query was generated from the PISP database using Standard Query Language. Cases of illness in which health effects were evaluated as definitely, probably, or possibly related with chlorpyrifos (used alone or in combination with other products) exposure between the years 2004

through 2014 were extracted and uploaded into MS Excel. Descriptive statistics were obtained using STATA v.15.0. The amount of pounds used in agricultural and non-agricultural applications, by year, was obtained from Pesticide Use Reports (PURs).

Findings

From 2004-2014, there were 246 associated cases of pesticide exposure stemming from 84 episodes involving chlorpyrifos. The number of illnesses varied throughout the 11 year period due to several multi-person episodes. Overall, the average number of chlorpyrifos episodes per year was 2.9; and, the average number of cases was 22.3 a year (Figure 1).

Figure 1. Cases and Episodes of Illness Due to Chlorpyrifos Exposure, 2004-2014.



The majority of illnesses were due to drift of pesticides (n=163, 66.2%), followed by residue (n=42, 17%), as shown in Table 1. Ingestion accounted for 12 (5%) cases, eight of which resulted from pesticides improperly stored and/or easily accessible to children.

Table 1. Chlorpyrifos Illnesses According to Exposure and Activity-All Use, 2004-2014

Exposure & Activity	Occupational	Non-Occupational	Total
Drift			
Applicator	4	1	**5**
Field Worker	60	-	**60**
Other activity	20	5	**25**
Packaging/Processing	2	-	**2**
Routine Indoor	21	16	**37**
Routine Outdoor	18	15	**33**
Unknown	-	1	**1**

Exposure & Activity	Occupational	Non-Occupational	Total
Drift			
Total Drift	**125**	**37**	**163**
Residue			
Applicator	1	-	**1**
Field Worker	21	-	**21**
Routine Indoor	15	5	**20**
Total Residue	**37**	**5**	**42**
Direct Spray/Squirt			
Applicator	2	-	**2**
Field Worker	1	-	**1**
Mixer/Loader	1	-	**1**
Total Direct Spray/Squirt	**4**	**0**	**4**
Other exposure			
Applicator	-	1	**1**
Emergency Response	1	-	**1**
Mechanical	1	-	**1**
Routine Outdoor	2	-	**2**
Transport/Storage/Disposal	1	-	**1**
Total Other exposure	**5**	**1**	**6**
Spill/Other Direct			
Applicator	1	1	**2**
Mixer/Loader	1	-	**1**
Routine Outdoor	-	1	**1**
Total Spill/Other Direct	**2**	**2**	**4**
Unknown exposure			
Applicator	11	-	**11**
Mixer/Loader	1	-	**1**
Routine Outdoor	-	1	**1**
Total Unknown exposure	**12**	**1**	**13**
Ingestion			
Mixer/Loader	1	-	**1**
Other	-	3	**3**
Routine Indoor	1	5	**6**
Routine Outdoor	1	1	**2**
Total Ingestion Exposure	**3**	**9**	**12**
Total Exposures	**171**	**75**	**246**

1. Applicator: Applies pesticides by any method or conducts activities considered ancillary to the application (e.g., cleans spray nozzles in the field).
2. Emergency response personnel responding to a fire, spill, accident or any other pesticide incident in the line of duty.

3. Field Worker: Works in an agricultural field performing tasks such as advising, scouting, harvesting, thinning, irrigating, driving tractor (except as part of an application), field packing, conducting cultural work in a greenhouse, etc. Researchers performing similar tasks in an agricultural field are also included.
4. Mechanical: Maintains (e.g., cleans, repairs or conducts maintenance) pesticide contaminated equipment used to mix, load or apply pesticides as well as the protective equipment used by individuals involved in such activities.
5. Mixer/Loader: Mixes and/or loads pesticides. This includes: (1) removing a pesticide from its original container (2) transferring pesticide to a mixing or holding tank (3) mixing pesticides prior to application (4) driving a nurse rig, or (5) transferring the pesticide from a mix/holding tank or nurse rig to an application tank.
3. Other: Activity is not adequately described by any other activity category. This includes but is not limited to: 1) individuals inside a vehicle; 2) dog groomers not handling pesticides; 3) individuals handling pesticide treated wood; 4) two or more activities with potential for pesticide exposure.
4. Packaging/Processing: Handles (packs, processes or retails) agricultural commodities from the packinghouse to and including the final market place (farm stand or produce department). This includes handling plants on nursery docks only (i.e., workers who did not enter growing areas). Field packing of agricultural commodities is classified as field worker.
5. Routine (Indoor or Outdoor): Conducts activities with minimal expectation of exposure to pesticides. This includes people in offices and businesses, residential structures, etc. who are not handling pesticides. This excludes field workers in agricultural fields. This includes gardeners who are not handling pesticides.
6. Transport/Storage/Disposal: Transports or stores pesticides between packaging and preparation for use.

Bystander exposure due to chlorpyrifos drift

The PISP defines a bystander as a person who experiences health effects from a pesticide application but is not involved in the application. Bystanders accounted for 217 (88.6%) of the reported illnesses and most were engaged in routine activities at the time of exposure (n=101, 41%), which meant they had minimal expectations of pesticide exposure (Table 2). Fieldworkers followed with 82 cases (38%). Eighty-seven (35.6%) drift-related cases involved air blast sprayers, with the notable exception of 24 cases that involved chlorpyrifos used in combination with bensulide applied by ground boom (Table 3).

Table 2. Activity of **Bystander** Illnesses According to Activity, Occupational Status and Use of Chlorpyrifos, 2004-2014

	Agricultural		**Non-Agricultural**		
Activity	**Occupational**	**Non-Occupational**	**Occupational**	**Non-Occupational**	**Total**
Field Worker	82	-	-	-	**82**
Routine indoor and outdoor	35	36	18	12	**101**
Other	5	20	-	3	**28**
Packaging/ Processing	1	-	1	-	**2**
Emergency Response	-	-	1	-	**1**
Transport/Storage/ Disposal	-	-	2	-	**2**
Unknown	-	1	-	-	**1**
Total	**123**	**57**	**22**	**15**	**217**

Table 3. Application Equipment and exposure type in Agriculture

	Application Equipment											
Exposure Type	**Airblast sprayers**	**Fixed wing aircraft**	**Helicopter**	**Ground boom**	**N/A**	**Ground, other**	**Manual, other**	**Over the Vine Boom**	**Pressurized Hose-line Sprayer**	**Hand pump sprayer**	**UNK**	**Total**
Drift	81	17	11	24	-	26	1	1	-	-	-	**161**
Residue	1	-	-	1	-	17	-		2	-	1	**22**
Unknown	3	-	-	-		6	-	2	-	1	-	**12**
Ingestion	-	1	-	-	1	-	-	-	-	-	-	**2**
Direct spray/ squirt	1	-	-	-	-	1	-	-	2	-	-	**4**
Spill/ other direct	1	-	-	-	-	1	-		1	-	-	**3**
Other	-	-	-	-	-	-	-	1	-	-	-	**1**
Total cases	**87**	**18**	**11**	**25**	**1**	**51**	**1**	**4**	**5**	**1**	**1**	**205**

Illness Type and mode of exposure

The PISP characterizes illnesses as systemic, respiratory, dermal (skin) or related to the eye. Most cases of chlorpyrifos exposure resulted in more than one type of illness reported (Table 4). Systemic and respiratory symptoms were among the most commonly reported illness type. Systemic symptoms reported include headache, nausea and dizziness. For respiratory, the most frequently reported symptoms were difficulty breathing, coughing and irritation of eyes and mucosal membranes (nose and throat).

Table 4. Illness Type(s) and Mode of Exposure to Chlorpyrifos, All-Use, 2004-2014.

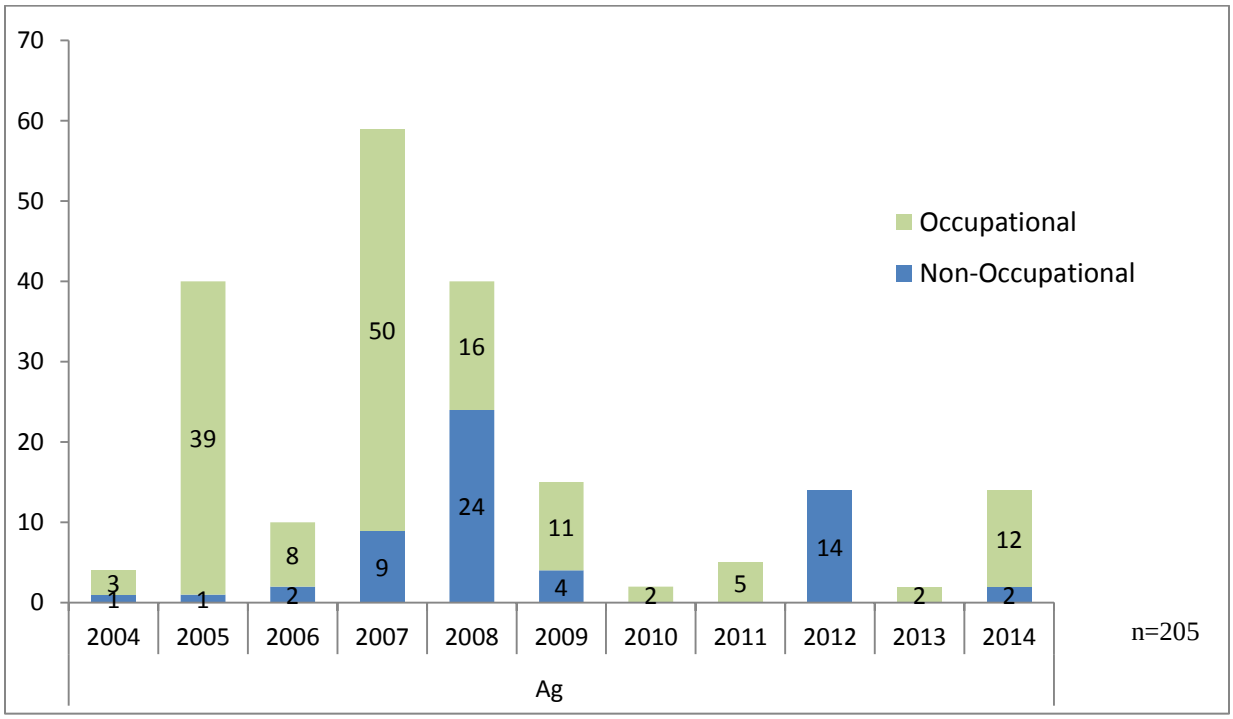
Illness Type(s)	**Exposure Type**							
	Drift[a]	**Residue[b]**	**Unknown**	**Ingestion**	**Other[c]**	**Spill/ Other Direct [d]**	**Direct Spray/ Squirt[e]**	**Total**
Systemic	49	23	8	8	2	2	1	**93**
Respiratory & Systemic	37	6	3	4	-	-	-	**50**

Respiratory	18	2	1		1			**22**
Skin & Systemic	14		-	-	-	1	1	**16**
Eye, Respiratory, & Systemic	9	4	-	-	-	-	-	**13**
Skin	7	2	1	-	-	1	-	**11**
Skin, Respiratory, & Systemic	10	-	-	-	-	-	-	**10**
Eye & Systemic	7	1	-	-	2	-	-	**10**
Skin, Eye, Respiratory, & Systemic	5		-	-	-	-	-	**5**
Eye & Respiratory	2	1	-	-	1	-	-	**4**
Skin, Eye, & Systemic	2	-	-	-	-	-	-	**2**
Skin & Eye	2	-	-	-	-	-	-	**2**
Skin, Eye, & Respiratory	-	1	-	-	-	-	-	**1**
Skin & Respiratory	-	1	-	-	-	-	-	**1**
Total	**163**	**42**	**13**	**12**	**6**	**6**	**4**	**246**

a. Drift: Spray, mist, fumes, or odor carried from the target site by air. Drift must be related to an application or mix/load activity.
b. Residue: The part of a pesticide that remains in the environment for a period of time following an application or drift. This includes odor after the completion of an application.
c. Other: Other known route of exposure not included in other exposure categories. This includes, but is not limited to: 1) Residue from a spill and 2) Exposure to smoke or pyrolitic products from a fire where pesticides are burning.
d. Spill/Other Direct: Any of the following: 1) Contact made during an application or mixing/loading operation where the material is not propelled by the equipment; 2) Expected direct contact during use (e.g. washing dishes in a disinfectant solution); 3) Leaks, spills, etc. not related to an application.
e. Direct Spray/Squirt: Material propelled by the application or mix/load equipment. Contact with the material can be by direct projection or ricochet. This includes exposure of mechanics working on application or mix/load equipment when the material is forced out by pressure.

Of the 246 cases involving chlorpyrifos in the years examined, 205 (83%) were agricultural and 40 (16%) were non-agricultural. Agricultural status could not be determined in one case. The majority of illness and injuries occurred while at work (n=171, 70%). Approximately, 60% (n=148) of the cases were both agricultural and occupational (Figure 2). The number of cases involving children under the age of 18 was 34 (14%), 24 of which involved the agricultural use of chlorpyrifos. The following sections concern exposures due to agricultural use of chlorpyrifos, since home use was removed in 2000.

Figure 2. Chlorpyrifos illnesses Caused by **Agricultural** Use, 2004-2014



Violations

Enforcement actions are still under review when the PISP evaluates investigative reports, so violations noted may not correspond exactly to the CDPR Enforcement Branch violations. The PISP records violation(s) information based on the available information. Violations, such as paper work infractions, are not contributory to the event. Violations resulting from episodes involving drift and residue are given in Table 5.

Table 5. Violations and Application Equipment Used in Chlorpyrifos **Agricultural** Episodes, 2004-2014

	Application Equipment										
Violation Type	**Airblast sprayers**	**Pressurized Hose-line Sprayer**	**Over the Vine Boom**	**Helicopter**	**Fixed wing aircraft**	**Ground boom**	**Ground, other**	**Manual, other**	**N/A**	**Hand pump sprayer**	**Total**
Total contributory violations	**66**	**1**	**2**	**9**	**15**	**6**	**25**	**-**	**1**	**-**	**125**
Other misuse	63	-	2	9	15	6	8	-	1	-	**104**

	Application Equipment										
Violation Type	**Airblast sprayers**	**Pressurized Hose-line Sprayer**	**Over the Vine Boom**	**Helicopter**	**Fixed wing aircraft**	**Ground boom**	**Ground, other**	**Manual, other**	**N/A**	**Hand pump sprayer**	**Total**
Failure to use required equipment	3	-	-	-	-	-	1	-	-	-	**4**
Early reentry	-	1	-	-	-	-	16	-	-	-	**17**
Total episodes without violations or with non-contributory violations	**21**	**4**	**1**	**2**	**2**	**35**	**8**	**1**	**-**	**1**	**75**
Unknown	-	-	1	-	1	1	1	-	-	-	**1**
Total episodes	**17**	**1**	**2**	**2**	**3**	**3**	**2**	**1**	**1**	**1**	**33**
Total cases	**87**	**5**	**4**	**11**	**18**	**42**	**34**	**1**	**1**	**1**	**204***

***excludes one case in which equipment was unknown and there was no violation**

a. Other misuse: Identifies some other violation of laws and regulations pertaining to pesticides. Other misuse violations indicate that exposure may have been avoided with regulatory compliance. Violations for failure to use required equipment and early reentry are separate entries.
b. Failure to use required equipment: Identifies failure to use required protective equipment when performing a task covered by law or regulation.
c. Early Reentry: Reentered a pesticide-treated area prior to the expiration of the restricted entry interval set by regulation or listed on the product label.
d. Non-Contributory: There is a violation(s), but it did not contribute to exposure (e.g., paperwork violations.)
e. None: Information provided in the investigation report shows no violation occurred. Specific statements reporting that "no violation was found" will be disregarded if the investigation report indicates otherwise.

Odor as a Contributing Factor

Odor as a causal factor for symptoms experienced was examined. In agricultural drift episodes, the presence of an odor was the most frequently recorded contributing factor leading to illness, (n=147, 79%). Chlorpyrifos has a "skunky", rotten egg, garlic odor. Pesticides containing chlorpyrifos are often formulated with high percentages of petroleum based solvents, which can add to the odor. These solvents have a kerosene or gasoline-like smell. Unfortunately, (most of) the investigation reports did not provide a description of the odor in a way that would enable the distinction between the odor associated with chlorpyrifos and that of a petroleum-based solvent.

Discussion

Overall, chlorpyrifos use in California has generally declined from 2005 to 2012, with the exceptions of the years 2010, 2011 and 2013 (Table 7). Use began to decrease again in 2014, and we expect to see this downward trend into the future. Both regulatory and socio-political conditions account for this present decline in the amount of chlorpyrifos used in agriculture. This trend is likely to continue because of the California designation of chlorpyrifos as a restricted material, requiring more efforts on the part of the growers to use this pesticide.

Table 7. Total pounds of Chlorpyrifos Used in California, 2004-2014

Year	Pounds	Change	Episodes
2004	1,787,240		
2005	2,031,348	244,108.3	40
2006	1,928,989	-10,2359	10
2007	1,442,521	-486,469	59
2008	1,368,568	-73,953.1	40
2009	1,246,560	-12,2007	15
2010	1,288,100	41,539.09	2
2011	1,298,930	10,830.24	5
2012	1,106,479	-1,92451	14
2013	1,469,300	36,2821.2	2
2014	1,308,855	-16,0445	14

In an effort to confirm this downward use trend, PISP staff reached out to the commissioners representing counties with the highest use of chlorpyrifos and where the decrease in chlorpyrifos use was especially notable. Their feedback indicted that growers have become disinclined to use this pesticide because several steps must be taken to comply with the 2015 US EPA regulation. Also, increasing public concern may be influencing the use of chlorpyrifos – stemming from articles and news stories stating that it is neurotoxic in utero, affecting birth outcomes and young child neurodevelopment. For example, almost all of the grape growers recently established best practices that allow them to be called "sustainable growers" if they take measures to protect the environment, that is, by refraining from the use of chlorpyrifos.

The presence of an odor remains a significant concern, as it is suspected to may play a role in causation of symptoms experienced by people exposed to chlorpyrifos products. These odors stem from the petroleum solvents contained in the chlorpyrifos products. Symptoms of exposure to these agents include irritation to the eyes, nose and throat, dizziness, nausea and headache. It remains important then, to learn whether the odor from the petroleum distillates may be the source for symptoms experienced. We recommend further investigation into the effect of the

petroleum-based ingredients to help determine if some of these illnesses can be attributed to odor from the solvents.

Summary of Episodes Affecting Five or More People

(21-TUL-05) Nine workers became ill while training grapes in Tulare County, 2005. The exposure was due to drift from an airblast application onto an almond orchard, which was approximately ½ mile away. Workers reported a strong unknown odor; and they experienced headaches, nausea and vomiting. The company did not measure the wind speed with an anemometer outside the orchard on the upwind side prior to applying the pesticide, as required by the label.

(29-TUL-05) Twelve employees of a box-making plant developed symptoms after detecting an odor in Tulare County, 2005. There was an ongoing chlorpyrifos application ¼ mile away from the plant. The commodity, oranges, was being treated with an airblast sprayer. Nine workers sought medical attention. Foliage samples confirmed drift. The applicator admitted to not using an anemometer to measure wind speed during application as required by the label.

(39-VEN-05) In 2005, Ventura County, six workers of a trucking company became ill due to drift from chlorpyrifos being applied to broccoli. The workers described the odor as smelling like garlic. One person reported he saw and felt a cloud of mist. Clothing and environmental samples were positive for the chemical applied.

(42-MER-05) Thirteen people became ill at a college in Merced County, 2005, due to residue from the floors in one building that had been treated with chlorpyrifos the previous night. They detected a strong odor, and experienced nausea and burning and itching eyes.

(13-VEN-05) Drift affected 11 workers in Ventura County, 2005. A ground application of chlorpyrifos was applied to a crop of radish seeds 350 feet away from fieldworkers harvesting spinach. They smelled an odor, and experienced dizziness, headache and stomach ache. Environmental samples were positive for chlorpyrifos residue. The company was cited for failing to protect people from drift.

(13-TUL-07) In 2007, an airblast application of chlorpyrifos affected seven residents of an agricultural community in Tulare County when agricultural drift reached their property. Symptoms reported included headache, dizziness and nausea, and a strong odor was detected. The company was cited for creating a health hazard by failing to turn off the air blast sprayer when he turned corners at the end of the rows.

(37-TUL-07) In 2007, two harvesting crews entered an orange grove 90 minutes after an application had been completed in Tulare County. The reentry interval was five days. Ten farmworkers became ill, experiencing symptoms of nausea, vomiting, headaches and dizziness

and tingling of hands and lips, and detected a strong odor. Clothing and environmental samples were positive for chlorpyrifos residue. Several violations were found, including that fields were not posted to alert people to the application.

(41-TUL-07) In Tulare County, 2007, pesticide drift onto a vineyard caused 17 workers to become ill, experiencing nausea, vomiting, headache, numbness in fingers and mouth and dizziness. Chlorpyrifos was used to treat an almond orchard, using airblast sprayers. Clothing samples and grape leaves were positive for the pesticide 500 feet away from the application site. The grower was cited for allowing drift onto people.

(33-MO-08) In 2008, 24 residents of an agricultural community in Monterey County became ill due to exposure to a pesticide drift. These residents were exposed to chlorpyrifos and bensulide that were applied using ground boom equipment. No violations were found.

(24-MON-08) In Monterey County, 2008, seven farmworkers, contracted to clear rocks adjacent to a vineyard, were made ill due to pesticide exposure. Two tractors making a ground application of chlorpyrifos, glyphosate and oxyfluorfen to the area bordering the vineyard, failed to cease the application when workers developed signs of exposure. A strong odor was detected like “bitter herb”. Another worker stated “I knew it was Lorsban, because I recognize the odor of that pesticide”. CIMIS wind data showed that wind was blowing toward the workers at speeds from 9 to 12 mph. Their clothing was positive for chlorpyrifos and oxyfluorfen. The grower was cited for allowing this drift onto the workers.

(31-KER-09) In Kern County, 2009, six landfill workers developed symptoms during a pesticide application onto oranges, growing south of the landfill. An airblast sprayer treated the trees with chlorpyrifos. A strong odor was detected, and the workers became nauseated and experienced coughing and dizziness. Clothing and ground samples were positive for chlorpyrifos.

(63-TUL-11) A family residing in Tulare County, 2011, became ill after their home was treated by an unqualified applicator. They were exposed to chlorpyrifos, bifenthrin and carbaryl. Swab analyses of their home found many areas and items positive for these pesticides.

(16-KER-12) In 2012, a bystander episode involved the aerial spraying of chlorpyrifos over a school bus. Fourteen children became ill and reported symptoms of itchiness, stomach aches and headaches, and they all detected an odor.

(49-SUT-14) In Sutter County, 2014, an aerial spraying (helicopter) of a walnut orchard affected a construction crew working on top of a levee. Eight workers became ill due to chlorpyrifos exposure. Hard hats were sampled and were positive for chlorpyrifos. Several crew members developed chemical pneumonia from this exposure.