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## M E M O R A N D U M

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SUBJECT: PROTOCOL FOR COLLECTION OF SAMPLES DURING INVESTIGATION OF FATALITIES SUSPECTED TO INVOLVE PESTICIDES

**Background:**

In California, 157 suspected pesticide fatalities were reported to the pesticide illness registry between 1982 and 2007. Cases occurred most frequently in Los Angeles, San Diego, Tulare, and San Joaquin counties, as indicated in Table 1.

**Table 1: Counties with Pesticide-Related Fatalities**

| County | Cases |
|---|---|
| Los Angeles | 42 |
| San Diego | 10 |
| Tulare | 8 |
| San Joaquin | 8 |
| Riverside | 7 |
| Fresno | 6 |
| Kern | 6 |
| Colusa | 5 |
| Sacramento | 5 |
| San Luis Obispo | 5 |
| Contra Costa | 4 |
| Madera | 4 |
| San Mateo | 4 |
| Kings | 3 |
| Orange | 3 |
| San Bernardino | 3 |
| Santa Clara | 3 |
| Solano | 3 |
| 19 Other Counties | 28 |
| **Total cases** | **157** |

**Table 2: Fatalities associated with pesticides reported in California Pesticide Illness Surveillance Program, 1982 – 2007**

| | | |
|---|---|---|
| ***Fumigants*** | ***42*** | |
| **Structural** | | **33** |
| Methyl bromide | | (20) |
| Sulfuryl fluoride | | (12) |
| Liquid nitrogen | | (1) |
| **Agricultural** | | **9** |
| Aluminum phosphide (2 intentional) | | (6) |
| Ethylene dibromide | | (2) |
| Calcium cyanide (intentional) | | (1) |
| ***Insecticides*** | ***31*** | |
| Cholinesterase inhibitors | | 29 |
| Lethane – thiocyanate insecticide (intentional ingestion) | | 1 |
| Methylene chloride (propellant in a structural insecticide treatment) | | 1 |
| ***Herbicides*** | ***13*** | |
| Arsenicals (both intentional) | | 2 |
| Bipyridyl (diquat/paraquat) (–6-7 intentional) | | 9 |
| Glyphosate (intentional) | | 1 |
| Ethylene plant growth regulator (explosion) | | 1 |
| ***Other pesticide active ingredients*** | ***8*** | |
| Chlorine water treatment | | 1 |
| Fenarimol fungicide (intentional) | | 1 |
| Lime sulfur (both intentional) | | 2 |
| Pine oil sanitizer | | 1 |
| Strychnine (2 intentional) | | 3 |
| **Investigations substantiating potential pesticide contribution** | **94** | |
| **Evidence against pesticide involvement or insufficient information** | **63** | |
| Alternative diagnoses* (heart attack, stroke, etc.) | | 31 |
| Vehicular traumatic injury | | 26 |
| Aircraft | | (22) |
| Tractor | | (4) |
| Murder/suicide victim | | 1 |
| Incomplete information | | 5 |
| **Total** | **157** | |

[a] Of the 29 ChE cases, there were 7 occupational poisonings, including 2 accidental ingestions. Of the 22 non-occupational ingestions, there were 19 suicides. The remaining cases, described in detail in Appendix Table 1, included an accidental childhood ingestion from an unsecured container (**Case #1982-1530**), an ingestion with insufficient information to determine whether it was suicidal, accidental (**Case # 1982-124**), and 1 ingestion with insufficient information to determine whether it was suicidal, accidental or deliberate poisoning by a second party (**Case # 1999-484)**

[b] Case investigations provided evidence that pesticide exposure did not trigger the event.

Details of the cases possibly, probably, or definitely related to pesticide exposure are shown in Appendix Table 1. Noteworthy findings included the 33 (78.6%) high percentage of the 42 fumigant cases related to structural pest control applications. There were 20 cases related to methyl bromide, 12 related to sulfuryl fluoride and 1 case of an applicator asphyxiated with liquid nitrogen (technically a spot treatment rather than a fumigant).

In the 33 structural fumigations, the victims included 19 people with no known connection to the fumigated structures they broke into, 12 residents of the fumigated structures, and a watchman hired to guard the building. The final case was an applicator asphyxiated by liquid nitrogen. Among the 12 residents, 8 broke in during fumigation, two were allowed to reoccupy an insufficiently decontaminated structure, one rented a guest house connected to the fumigated structure by forgotten conduit, and one apparently failed to vacate the structure before fumigation.

Two agricultural fumigant cases involved workers at a chemical dealership who entered a tank contaminated with the now prohibited fumigant ethylene dibromide. Of the 6 aluminum phosphide cases, two were intentional ingestions, and the other four victims broke into fumigated rail cars. The remaining case involved a murderer's use of calcium cyanide to commit suicide.

Of the 31 fatal insecticide exposures, 29 (93.5%) involved either carbamate or organophosphate (OP) cholinesterase inhibitors. Of the 13 herbicide cases, 9 (69.2%) involved bipyridyl compounds (either paraquat or diquat). Among the 52 non-fumigant deaths, 35 were intentional, and the intent of one paraquat victim was not determined.

Four occupational exposures to cholinesterase inhibitors were highly ambiguous. Three involved aerial applicators who crashed while applying potent inhibitors. The fourth victim collapsed in a recently treated field. Investigations of these deaths did not include tests to confirm or exclude intoxication.

In two additional cases there was evidence of cholinesterase inhibition. The first case involved an aerial applicator applying the OP insecticide profenofos who crashed his plane after making contact with power lines. Post mortem testing showed normal acetyl cholinesterase (AChE), but depressed butyryl cholinesterase (BuChE). Although depressed BuChE levels can frequently occur without causing poisoning, it is possible that absorption of profenofos or another cholinesterase (ChE) inhibitor caused impairment of judgment that contributed to the crash. The second case involved an applicator who ingested parathion, possibly from trying to clear a spray nozzle. He developed acute intoxication and was unable to describe what happened. Post mortem samples showed ChE depression, elevated urine p-nitrophenol, parathion and oil from the tank mix in the gastric contents. A final occupational case involved an accidental ingestion of the insecticide demeton stored inappropriately in an unlabeled container. It was probable that the

death was related to the ingestion, but no post-mortem evaluation of cholinesterase was carried out.

Sixty-three cases were classified as unrelated to pesticide exposure or with insufficient information to classify. These included 22 aviation accidents (34.9%), 31 cases involving myocardial infarction, stroke or other unrelated medical condition (48.4%), 4 tractor accidents (6.3%), 5 cases with incomplete information (7.8%) and 1 murder victim whose murderer then used a pesticide to commit suicide.

Selected cases for which bio-monitoring was used to rule out possible involvement of pesticides are shown in Appendix Table 2. These included the case of a 62-year-old man who collapsed during 90-100 degree weather while flagging for an application of methomyl in Yolo County (case #**1990-1755**). Post-mortem testing of blood and brain ruled out significant cholinesterase inhibition and gross pathology showed a large myocardial infarction. The absence of any detectable serum bromide ruled out poisoning in a 48 year old fumigation crew worker who also collapsed during hot weather in 1993 in Kern County (case #**1993-1356**). As in the 1990 Yolo County case, a myocardial infarction was demonstrated at the autopsy. In a 2006 case from Contra Costa County, blood levels of isopropanol and acetone demonstrated ingestion of pine oil, but levels far below those associated with fatal outcome in previously reported cases (case #**2006-372**).

**Protocols for Collection of Samples during Investigation of Fatalities Suspected to Involve Pesticides**

The suggested protocols (for measuring pesticide metabolites and other types of biological monitoring or sample collection) may prove helpful in disproving as well as confirming the role of a pesticide in causing a fatal illness. The protocols are summarized in Table 3 and additional details are given in the appendix.

| Table 3: Summary of recommendations for biomonitoring | | |
|---|---|---|
| **Condition** | **Matrix, fluid or tissue** | **Considerations** |
| Ingestion | Stomach contents | Measure volume of contents and keep a substantial sample for analysis |
| | Clothing | Often contains sufficient residue to detect |
| | Tissue | Liver and kidney are most probable locations for pesticide detection |
| **Insecticide intoxication** | | |
| Organophosphate | Blood | Pathophysiology: permanent inactivation of esterases with overlapping substrate affinities, including the ability to catalyze hydrolysis of acetylcholine. When enzyme is sufficiently inhibited, acetylcholine accumulates at synapses & neuromuscular junctions.<br>The enzyme associated with red blood cells (RBC cholinesterase) is chemically identical to the form found at synapses, the inhibition of which produces the toxic effects.<br>Some organophosphates preferentially inhibit the form of the enzyme that is produced by the liver and circulates in the plasma (plasma, serum, "pseudo", or butyryl cholinesterase.)<br>Both enzymes are fairly stable in storage, but may be inhibited by the anticoagulant sodium fluoride.<br>Recommendation: collect samples in heparinized tubes (green tops); freeze pending analysis. |
| | Urine | Tests are available for parent compounds and for several common metabolites. In cases of massive ingestion, the parent compound may be identified in urine.<br>Most organophosphates break down to one of six types of alkyl phosphate, which are rapidly excreted in urine. Analysis for alkyl phosphates serves as a non-specific screening tool for organophosphate exposure.<br>Tests are available for several metabolites that are specific to individual organophosphates: paranitrophenol (EPN, methyl and ethyl parathion), 3-methyl-4-nitrophenol (fenitrothion), trichloropyridinol (chlorpyrifos), dicarboxylic acid (malathion)<br>Recommendation: freeze pending analysis. |

| Table 3: Summary of recommendations for biomonitoring | | |
|---|---|---|
| **Condition** | **Matrix, fluid or tissue** | **Considerations** |
| | Vitreous fluid | Sometimes used as a surrogate for butyryl cholinesterase.<br>Reference values are not well established.<br>Recommendation: To use this approach, collect 5 - 10 comparison samples from unexposed subjects. |
| N-Methyl Carbamate | Blood | Pathophysiology as for organophosphates, except that cholinesterase inactivation reverses spontaneously, so tests must be run promptly to detect inhibition.<br>Recommendation: chill samples promptly, transmit frozen, assay ASAP |
| | Urine | N-methyl carbamates do not form alkyl phosphates. Several common carbamate insecticides (bendiocarb, carbofuran, and propoxur) give rise to 1-naphthol as a detectable leaving group metabolite. |
| Organochlorine | Blood | Except for endosulfan and dicofol, most organochlorine pesticides have been removed from the market. Acute exposures occasionally occur to pesticides stored for decades. Tests are available to detect: aldrin/dieldrin, chlordane, DDT, dicofol, endosulfan, and methoxychlor. |
| | Fat | Organochlorines are lipophilic and tend to accumulate in fat, where they remain indefinitely. |
| **Halogenated fumigant intoxication** | | |
| Methyl bromide | Blood | Bromide level: reference level is < 5 mg/L. Fatal methyl bromide cases are usually associated with levels > 50 mg/L. Methyl bromide is more toxic than the dissociated bromide ion. |
| Ethylene dibromide | Blood | Bromide level, as for methyl bromide; has not been registered for sale since 1987. |

**Table 3: Summary of recommendations for biomonitoring**

| Condition | Matrix, fluid or tissue | Considerations |
|---|---|---|
| Sulfuryl Fluoride | Blood | Fluoride level; reference level: 0.01 - 0.2 mg/L. Fatal cases have had levels reported as 5.1 - 38 mg/L. Fluoride is probably the toxicologically active species. |
| Phosphine (directly or from pesticides that generate phosphine) | | Products are available that contain aluminum phosphide, zinc phosphide, and magnesium phosphide. These compounds react with moisture to liberate phosphine ($PH_3$). Phosphine gas is also available for use as a fumigant. Oxidation of $PH_3$ yields phosphate – so metabolites are not a useful measure of exposure. |
| | Blood | In some aluminum phosphide ingestion cases, serum aluminum has been used as a marker. This is probably not useful in cases of inhalation. |
| | Air | Air samples taken over the body (as soon as possible after death) may be the best indicator of exposure to phosphide fumigants. |
| Methyl isothiocyante (MITC) (directly or from pesticides that generate MITC) | | MITC is available for use as a wood preservative and is generated during soil fumigation and other uses by the reaction of metam-sodium, metam-potassium or dazomet with moisture A thiocyanate insecticide (Lethane) has not been registered since 1987. |
| | Blood | Thiocyanate can be detected in serum or whole blood. No reference levels have been published. |
| | Urine | Thiocyanate can be detected in urine. No reference levels have been published. |
| Cyanide | | Two cyanide products continue to be registered as of 2009. |
| | Blood | Cyanide can be detected in serum |
| | Air | A Draeger tube is available to test for cyanide presence in air. |

**Table 3: Summary of recommendations for biomonitoring**

| Condition | Matrix, fluid or tissue | Considerations |
|---|---|---|
| Nitrogen | | Occasionally used as a spot treatment for localized termite infestation; no chemical test is useful; evaluate for pulmonary edema related to asphyxia. |
| **Herbicides** | | |
| Diquat (bipyridyl) | Serum<br>Urine | 0.45- 0.55 ppm detected in a fatal case.<br>1.15 and 1.85 ppm detected in the fatality in which serum levels were measured. Diquat levels may also be useful for evaluating ingestions of mixed formulation products (e.g., a relatively new product containing a mixture of diquat and glyphosate). |
| Paraquat (bipyridyl) | Urine | Levels up to 0.32 ppm have been reported following occupational exposures not associated with illness. All tests on the urine of fatal cases have shown more than 1 ppm |
| **Other Pesticides** | | |
| Alachlor (chloroacetanilid) | | Detectable in blood, serum/plasma, urine |
| Arsenicals | Urine | |
| 2,4-dichloro-phenoxyacetic acid (2,4-D) | | Detectable in blood, serum & plasma |
| Dicamba | | Detectable in blood serum/plasma, urine |
| MCPA | | Detectable in blood, serum/plasma, urine |
| 2,4,5,-T | | Detectable in blood, serum/plasma, urine |
| Picloram | | Detectable in serum/plasma, urine |
| Triclopyr | | Detectable in serum/plasma, urine |

**Table 3: Summary of recommendations for biomonitoring**

| Condition | Matrix, fluid or tissue | Considerations |
|---|---|---|
| Pendimethalin | | Detectable in blood, serum/plasma, urine |
| Trifluralin | | Detectable in blood, serum/plasma, urine |
| **Fungicides and Disinfectants** | | |
| Dithiocarbamates | | Includes disulfiram, maneb, and thiram. Metabolism of disulfiram produces diethyldithiocarbamate (DEDTC), a metabolite available at clinical laboratories because disulfiram is contained in the pharmaceutical product Antabuse. Ethylene thiourea (ETU) is a metabolite of all the compounds in this class, but analysis for ETU is not currently performed by any of the clinical laboratories. |
| Pine oil | | Typical products contain large amounts of isopropanol; test for serum levels of isopropanol, acetone. |
| **Rodenticides** | | |
| Strychnine | | Detectable in blood, serum/plasma, urine |
| Anticoagulant rodenticides | | Includes bromadiolone, coumadin, diphacinone; not common causes of death, but can be detected in serum/plasma. Tests for coumadin in blood and urine are also available. |

**Appendix - Summary of post-mortem protocols by use category**

**Insecticide exposure cases:**

Because a large majority of fatal insecticide cases involve cholinesterase inhibitors, the discussion below focuses on those compounds.

**RBC acetylcholinesterase (AChE) and serum or plasma (Butyryl) Cholinesterase (BuChE) to identify the presence of cholinesterase inhibition.** Cholinesterase is stable post-mortem for a considerable period of time, but may be inhibited by sodium fluoride (often used as an anti-coagulant for post-mortem blood samples). It is preferable to collect the blood in a heparinized tube.

**Additional considerations:** Samples of vitreous fluid are sometimes collected from the eye as a surrogate for BuChE. If this is done, comparison samples should be collected from 5-10 unexposed subjects because reference values for BuChE in vitreous are not well established.

Samples of cholinesterase in cases of suspected carbamate intoxication should be run as quickly as possible after collection because of possible in vitro regeneration of un-inhibited enzyme

A separate serum sample should also be collected and stored frozen for further analysis if exposure to other compounds is a consideration.

**Urine for pesticide metabolites**:

Organophosphate urinary metabolites: least specific - alkyl phosphates, alkylthiophosphates

Leaving group urinary analysis: paranitrophenol (EPN, methyl and ethyl parathion), 3-methyl-4-nitrophenol (fenitrothion), trichloropyridinol (chlorpyrifos), dicarboxylic acid (malathion ingestion)

Selected carbamate insecticides that have 1-naphthol as a leaving group metabolite: bendiocarb, carbofuran, and propoxur

Active ingredients may show up in the urine following massive exposure and it may be possible to identify the compound involved from urine sample. Sample may be stored frozen until analysis.

**Suspected deliberate or accidental ingestion**

Stomach contents for active ingredient

Clothing samples for active ingredient

Tissue samples (e.g., liver or kidney) may also be analyzed for active ingredients

**Thiocyanate insecticide or thiocyanate**

Lethane is no longer registered, but may be evaluated by means of serum, tissue or urine thiocyanate levels. The same test may be useful for thiocyanate releasing fumigants (see below). Reference levels for serum and urine thiocyanates have not been published. Low levels may possibly be present in either blood or urine from dietary sources (e.g., from broccoli and other cruciferous vegetables).

**Other insecticides**

Organochlorine compounds that can be monitored in blood and other tissues including:

- Chlordane
- DDT
- Aldrin/dieldrin
- Methoxychlor
- Endosulfan
- Dicofol

**Fumigant exposure cases**

Fatal exposure to fumigants most often takes place because of accidental or deliberate entry into treated spaces. Very occasional cases occur because of migration of fumigant between a treated space and an adjoining building. Intoxication with street drugs or alcohol occurs frequently as a contributing factor, usually detected by routine post-mortem toxicology screening.

**Phosphide fumigants**

Air samples in cases of suspected poisoning with phosphide fumigants (aluminum phosphide, zinc phosphide, or magnesium phosphide):

Air samples taken over the body (as soon as possible after death) may be the best indicator of exposure to phosphide fumigants. Fatal cases reported around the world typically involve deliberate ingestion, but cases reported in California have included violation of rail cars

fumigated in transit. Phosphides break down generates $PH_3$, oxidation of $PH_3$ yields phosphate – so metabolites are not a useful measure of exposures.

In some aluminum phosphide ingestion cases, serum aluminum has been used as a marker. This is probably not useful in cases of inhalation.

**Halogenated fumigants**

Serum bromide in case of methyl bromide, ethylene dibromide exposure

**Reference levels:** less than 5 mg/L; fatal methyl bromide cases usually associated with levels > 50 mg/L

Serum fluoride in case of sulfuryl fluoride exposures

**Reference levels:** There have been occasional reports of fatal illness associated with sulfuryl fluoride reported in the medical literature. In 1966, Takay reported a case involving a 4-hour exposure to a 30 year old man under conditions of limited ventilation. He developed nausea, vomiting, crampy abdominal pain, and pruritus, and left the area. He was admitted to the hospital and found to have eye and upper respiratory irritation and rhonchi in his lungs. He was observed for 4 days and discharged without symptoms. The report did not include a quantitative serum fluoride test, but indicated that a qualitative test was positive on the day of admission. Additional cases were described in 1986 by Schuerman, with clear documentation of markedly elevated fluoride levels (50.4 mg/L and 20 mg/L). Two deaths associated with reported failure to clear structure of sulfuryl fluoride were described in 1986 in the CDC journal the MMWR. The fluoride level was 0.5 mg/L in one case and not reported in the other. The limited information included in the publication made it difficult to determine whether either death was related to sulfuryl fluoride or not. Four cases in California where fluoride testing was done after death from sulfuryl fluoride exposure showed levels of 7.4 mg/L, 5.1 mg/L, 32 mg/L, and 38 mg/L, respectively.

**Background or reference levels for serum fluoride:** 0.01 – 0.2 µg fluoride/mL serum, equivalent to 0.010-0.2. mg fluoride/L

**Other fumigants or volatile gases**

Liquid nitrogen – Evaluate for pulmonary edema related to asphyxia
Cyanide – Serum cyanide levels, Draeger samples to detect off-gassing
MITC Releasing Fumigants - Thiocyanate serum, blood, urine

## Herbicides

In cases of suspected ingestion, the identity of the ingested material can be confirmed by analyzing the gastric contents for active ingredient. (You may be able to arrange analysis of a frozen sample through the state laboratory – see section on laboratory resources in the appendix below.)

### Bipyridyls – Paraquat, Diquat

Paraquat urine levels associated with fatal cases may exceed 100 ppm and invariably exceed 1 ppm. Levels up to 0.32 ppm have been reported following occupational exposures not associated with illness.

Urine levels of diquat in a fatal case (actually collected prior to death) ranged between 1.15 and 1.85 ppm. Serum levels ranged from 0.45 - 0.55 ppm in the same case. Diquat levels may also be useful for evaluating ingestions of mixed formulation products (e.g., a relatively new product containing a mixture of diquat and glyphosate).

### Other herbicides:

The following tests are available from one or more commercial laboratories:

Alachlor - blood, serum/plasma, urine
Arsenicals - urine arsenic
Atrazine, simazine, cyanazine, propazine - blood, serum/plasma, urine
2,4-Dichlorophenoxyacetic Acid - blood, serum/plasma urine
Dicamba - blood, serum/plasma, urine
MCPA herbicide - blood, serum/plasma, urine
Metribuzin - blood, serum/plasma, urine
2,4,5,-T - blood, serum/plasma, urine
Picloram: serum/plasma, urine
Triclopyr: serum/plasma, urine
Pendimethalin: blood, serum/plasma, urine
Trifluralin: blood, serum/plasma, urine

## Fungicides, Disinfectants and Rodenticides

In cases of suspected ingestion, the identity of the ingested material can be confirmed by analyzing the gastric contents for active ingredient. (You may be able to arrange analysis of a

frozen sample through the state laboratory – see section on laboratory resources in the appendix below.)

**Fungicides, Disinfectants**

Thiuram, disulfiram maneb, (DEDTC metabolite)
Pine oil ingestion cases – serum levels of isopropanol, acetone

**Rodenticides**

Strychnine: Blood, Serum/Plasma, Urine

Anticoagulant rodenticides can be tested for, but are not commonly a cause of fatal poisonings.

Coumadin: Blood, Serum/Plasma, Urine
Bromadiolone: Serum/Plasma
Diphacinone: Serum/Plasma

**Laboratories Resources**

For pesticide active ingredients from bulk samples or from gastric contents.

Contact: Worker Health and Safety, California Department of Pesticide Regulation
Telephone: 916-445-4222.
Contacts: Sue Edmiston, Environmental Program Manager II
George Farnsworth, Environmental Program Manager I
Louise Mehler, M.D., Ph.D, Epidemiologist, Pesticide Illness Surveillance Program

A list of laboratories approved by the state of California for cholinesterase monitoring is available online at:
http://www.cdph.ca.gov/certlic/labs/Documents/CHE%20LAB%20list%2001012007.pdf.

The current list includes hospital or independent clinical laboratories in agricultural areas of California, large laboratories with regional laboratories throughout the state, and some out-of-state laboratories.

Laboratories specializing in toxicology testing include:
National Medical Services (www.nmslabs.com) and Pacific Toxicology (www.pactox.com)

**Appendix Table 1 - Fatalities related to pesticides reported in California 1982-2007 by use category and active ingredients**

| Use category/ Active Ingredient | No. of Cases | Case Details |
|---|---|---|
| **Fumigants** | **42** | |
| **Structural** | **33** | |
| Methyl Bromide | 20 | Cases all related to structural fumigation: post-mortem blood bromide available from investigation file in only 3 cases, ranging from 110 mg/L - 270 mg/L. One case died 4 months after initial exposure; methyl bromide listed as a possible contributing cause, along with chronic alcoholism. No fatalities were found related to agricultural use, but a post mortem blood sample was used to rule out methyl bromide poisoning in case #**1990-1755.** Additional details of the case are discussed in Table 2. |
| Sulfuryl Fluoride | 12 | All structural fumigation related deaths. Post-mortem fluoride levels available in 5 cases; results were 5.1 mg/L, 7.4 mg/L, 24 mg/L, 32 mg/L, and 38 mg/L. |
| Liquid Nitrogen | 1 | Liquid nitrogen escaped from a wall void during a spot termite treatment and caused an applicator to lose consciousness and suffer a cardiac arrest. The autopsy showed only pulmonary congestion, consistent with asphyxia. There was no coronary disease or evidence of drug abuse. |
| **Agricultural** | **9** | |
| Aluminum Phosphide | 6 | Case #s **1989-474, 2003-1075, 2005-1307, 2005-1308** - Poisoning inside treated railroad cars.<br>Case #**2003-468** - Suicide in motel room.<br>Case #**2003-515** - Ingestion. |
| Ethylene Dibromide | 2 | Case #s **1982-2200, 1982-2201** - A worker entered a tank to clean it and lost consciousness; a co-worker lost consciousness while attempting a rescue. Both died afterwards. Post mortem bromide levels were 830 mg/L in the first worker and 500 mg/L in the co-worker. |
| Calcium Cyanide | 1 | Case #**1986-1912** - A licensed pesticide applicator apparently stabbed his wife and then committed suicide by inhaling or ingesting calcium cyanide. The cyanide was a pesticide, but not one used by the decedent's employer. |
| **Insecticides** | **31** | |
| **Cholinesterase Inhibitors** | **29** | |
| **Carbamates** | **4** | |
| Methomyl | 1 | Case #**1986-1037** - Pilot crashed his helicopter after making 180 degree turn. No mechanical reason for crash apparent. There was no post-mortem reported but it was considered possible that he had chronic exposure to ChE inhibitors because his cockpit did not have doors and spray booms were mounted in front of the plane. |
| Carbaryl | 1 | Case # **2007-1167-** A man intentionally ingested large amounts of concentrated carbaryl in an apparent suicide attempt. The doctor intubated him and admitted him to |

**Appendix Table 1 - Fatalities related to pesticides reported in California 1982-2007 by use category and active ingredients**

| Use category/ Active Ingredient | No. of Cases | Case Details |
|---|---|---|
| | | the ICU where he remained for 18 days until he passed away. |
| Carbofuran | 1 | Case #**1999-484** - A 58-year-old woman died on the way home from the airport. Post-mortem analysis showed toxic levels of carbofuran in her blood and gastric contents. It could not be determined whether the ingestion was a suicide, an accident, or deliberate poisoning by another person. |
| Aldicarb | 1 | Case #**2003-187** - An agricultural applicator committed suicide; no autopsy was performed because of concerns regarding possible exposure to medical examiner's staff. |
| **Organo-phosphates** | **25** | |
| Chlorpyrifos | 1 | Case #**1982-34 -** The decedent threatened store employees before ingesting chlorpyrifos, 2,4-D and an anti-coagulant. No additional medical details were included in the investigation report. It is likely that the death was attributable to the chlorpyrifos rather than the other active ingredients. |
| Profenofos | 1 | Case #**1987-1661** - A 46-year-old crop duster applying profenofos crashed his plane 8/13/1987 after making contact with power lines. Post mortem testing showed AChE - 1.16 Δ pH/Hr (reference range: 0.55-1.25 Δ pH/Hr), BuChE 0.03 Δ pH/Hr (reference range 0.41-1.65 Δ pH/Hr). Routine monitoring conducted prior to accident was within normal limits: **8/10/1987:** AChE 9756 U/L (4000 U/L -10, 600 U/L reference range BuChE 2687 U/L (1000 U/L -3900 U/L reference range); **7/21/87** 3202 U/L, 10137 U/L: **6/15/1987** 3287 U/L, 9988 U/L; **3/32/1987** 3411 U/L, 9747 U/L; **2/6/87** 3102 U/L, 10083 U/L. Because of the depressed BuChE levels, impairment from OP exposure was considered to be a possible contributory cause of death. |
| Methamidophos, Fenvalerate | 1 | Case #**1985-1837** – A worker collapsed in field the same day it was treated with methamidophos and fenvalerate. Co-workers started for a hospital, then took him to Mexico when convinced he had died. The autopsy in Mexico did not investigate possible OP poisoning and body was embalmed afterwards. A repeat autopsy in the U.S. showed skin contamination with methamidophos, but cholinesterase or urinary metabolites testing were not possible. |
| Parathion, Methyl Parathion, Dimethoate | 1 | Case #**1990-817** – A pilot crashed with another plane while applying mixture of parathion, methyl parathion and dimethoate. Details of post-mortem evaluation not available in the investigation file. Multiple evaluations were performed on emergency response personnel. |
| Mevinphos, Methomyl | 1 | Case #**1986-1201** – A pilot with 8 years' experience was killed in crash while applying mevinphos and methomyl. No autopsy was performed as the body was badly burned. The pilot was not involved in mix/loading. |

**Appendix Table 1 - Fatalities related to pesticides reported in California 1982-2007 by use category and active ingredients**

| Use category/ Active Ingredient | No. of Cases | Case Details |
|---|---|---|
| Parathion | 1 | Case #**1990-183** – A professional agricultural applicator ingested parathion, possibly while trying to clear a spray nozzle. He developed acute intoxication and was unable to describe what happened. Post mortem samples showed ChE depression, elevated urine p-nitrophenol, and a mixture of parathion and oil from the tank mix in the gastric contents. |
| Demeton | 1 | Case #**2002-980 -** An elderly grower regularly used unlabeled bleach bottles both to carry drinking water and to store agricultural chemicals. While spraying herbicides in a walnut orchard, he drank from a bottle that proved to contain demeton concentrate (bulk sample contained 15.5% active ingredient). A brief post-mortem evaluation, with only an external examination, was performed. Only routine screening toxicology was performed showing therapeutic levels of diphenhydramine, temazepam and lorazepam. |
| Dimethoate | 1 | Case #**1998-1 -** Intending to commit suicide, an elderly woman drank a pesticide. Her caretaker found her and called 911. At the hospital, staff believed she did not drink much and did not use atropine or 2-PAM. She deteriorated rapidly and died within 6 hours |
| Phorate | 1 | Case #**1982-1530 -** A 22-month-old child was playing in grandparents' yard where a can of thimet was found inside a coffee can. He suddenly became nauseated and fell down. Parents rushed him to hospital. He did not recover and died 4 days later from poisoning complications. A bulk sample of material showed 0.9% thimet. AChE level 0.10 (ref range 0.67 – 0.86), BuChE 0.25 (ref range 0.70-0.97). The autopsy showed pneumonia and cerebral edema. |
| Diazinon | 3 | Case #**1983-2249 -** Homeowner was found on her garage floor unconscious. This was a suicide.<br>Case #**2000-959 -** A 49-year-old woman attempted suicide by slitting her wrist and drinking up to 3 pints of diazinon. There were no medical details contained in the investigation file.<br>Case # **2007-435** – A 53-year old man with history of drug and alcohol abuse ingested diazinon and a rodenticide after learning he had liver cirrhosis. He spent 17 days in the hospital where his condition deteriorated culminating in his death. |
| Malathion | 13 | 12 cases involved suicide by ingestion. For an additional case (**# 1982-124**), the victim was intoxicated with alcohol when he ingested a lethal quantity of malathion from an unlabeled brown jug. From the circumstances, it could not be determined whether the ingestion was accidental or intentional. |
| **Other Insecticides** | **2** | |
| Methylene Chloride | 1 | Case #**1985-963 -** A 29-year-old applicator found to have a cardiomyopathy after suffering cardiac arrest: he was applying a chlorpyrifos formulation to kill termites in |

**Appendix Table 1 - Fatalities related to pesticides reported in California 1982-2007 by use category and active ingredients**

| Use category/ Active Ingredient | No. of Cases | Case Details |
|---|---|---|
| | | a crawl space at the time of his death. The post-mortem showed 69 mg/l methylene chloride in blood, possibly related to an inert ingredient in the chlorpyrifos or one of the other formulations he had used. |
| Lethane | 1 | Case #**1982-**2544 - A woman died 6 days after ingesting insecticide containing lethane (2-(2-butoxy ethoxy) ethyl thiocyanate). There was no post-mortem in the investigation file. |
| Mixed exposures | 2 | |
| **Herbicides** | **13** | |
| Arsenicals | 2 | Case #**1999-1378** - A 58-year-old man ingested an unknown amount of pesticide. He was hospitalized and expired 3 days later. According to the initial case information, he possessed the pesticide for a long time, possibly 20-30 years. No additional investigation of the case was conducted.<br>Case #**1986-1195** - A 42-year-old man committed suicide, ingesting a weed killer with 40% arsenic. He was pronounced dead on arrival at a hospital emergency room. No additional medical information was available in the investigation file. |
| Bipyridyls - Diquat | 4 | Case #**1982-1493** - A 2-year-old drank diquat stored in a coke bottle **a**nd died despite hemodialysis. The blood level of diquat was 1.7 mg/L and urine level 200.2 mg/L at the time of initial hospital admission.<br>Case #**1989-47** - A man was found dead in his cabin with a one quart container of diquat nearby. The coroner found erosive esophagitis and determined the death a suicide caused by ingestion of diquat, but additional details were not available.<br>Case #**1997-213** - A landscape worker committed suicide by drinking diquat. No medical details included in the investigation report.<br>Case # **2007-1224** - a 56-year old woman apparently drank about a quart of herbicide concentrate, containing diquat and glyphosate, to commit suicide. She was admitted to the hospital ICU, where her condition deteriorated rapidly & she died within a day. |
| Bipyridyls - Paraquat | 5 | Case #**1983-2623** - A subject ingested paraquat, in a successful suicide attempt. No medical details available in the investigation report.<br>Case #**1986-216** - The manager of a golf course died after ingesting paraquat. No medical details available in the investigation report.<br>Case #**1989-2184** - Suicide via ingestion of paraquat, PCP and alcohol. Paraquat confirmed in plasma of deceased; unable to determine how obtained.<br>Case #**2003-169 - A** 49-year-old man had 2 coffee cups in the garage, one with coffee, the other with paraquat. He mistakenly sipped from the cup with paraquat. He immediately spit it out and went to the hospital within an hour. He died 7 days later. Additional medical details were not available.<br>Case #**2003-435** - A 42-year-old man committed suicide by ingesting paraquat. A |

**Appendix Table 1 - Fatalities related to pesticides reported in California 1982-2007 by use category and active ingredients**

| Use category/ Active Ingredient | No. of Cases | Case Details |
|---|---|---|
| | | summary report from the coroner reported copious amounts of paraquat in the gastric contents and blood, but details of testing were not reported. |
| Glyphosate product | 1 | Case #**2005-74** - A suicidal woman entered treatment two days after drinking Roundup (contains glyphosate), according to her statement. She received intensive care for nine days before dying. Some abnormalities were attributed to Roundup's surfactant; others suggested an additional toxicant. |
| Ethylene | 1 | Case #**1999-1053** - An ethylene treatment (growth regulator) chamber exploded killing a worker who was in an adjacent hallway. |
| **Other pesticide active ingredients** | **8** | |
| Chlorine | 1 | Case #**1990-1684** – A worker tried to repair a chlorine injection leak without respiratory protection. He soon developed chest pain and shortness of breath, possible permanent lung damage. He died 3 months later following heart surgery, with lung damage from the chlorine accident identified as a contributing factor. |
| Fenarimol | 1 | Case #**1996-53** - A 24-year-old man committed suicide by drinking an unknown amount of fenarimol. The odor of the ingested material, or possibly one of its metabolites, made several hospital staff ill. However, it was not possible to conduct sampling to identify a specific air contaminant. |
| Lime-Sulfur | 2 | Case #**1986-381** - A 27-year-old male committed suicide by ingesting "dormant disease control". No details of the post-mortem evaluations were included in the investigation report.<br>Case #**1989-476** - A 23-year-old woman committed suicide, ingesting an unknown amount of lime-sulfur. Post-mortem toxicology testing proved negative for illicit drugs, but showed sub-therapeutic levels of the anti-seizure drug phenytoin (1.7 µg/ml; therapeutic range for adults 10-20 µg/ml). No analysis of stomach contents was reported. |
| Pine Oil | 1 | Case #**2002-788** – An elderly person with Alzheimer's disease opened a sealed disinfectant container and drank some believing it to be apple juice. Her son found her lying on the kitchen floor and immediately took her to the hospital. She died 4 days later. |
| Strychnine | 3 | Case #**1982-245** - A teenager and 2 friends inhaled strychnine particles, apparently thinking it was "crank," or amphetamine. He developed symptoms and was rushed to the hospital. He died later. His friends were in stable condition.<br>Case #**1993-2085** - A 47-year-old man committed suicide by ingesting strychnine-coated seeds. He also shot himself in the forehead with a .22 caliber weapon which caused minimal damage. His body was found in advanced state of decomposition. Seeds found in his stomach were identified as a rodenticide product containing 0.02% |

**Appendix Table 1 - Fatalities related to pesticides reported in California 1982-2007 by use category and active ingredients**

| Use category/ Active Ingredient | No. of Cases | Case Details |
|---|---|---|
| | | strychnine.<br>Case #**2000-55 -** A 41-year-old man reportedly mixed half a bottle of strychnine gopher bait in tea and drank it. Paramedics reported that he developed shakiness, tachycardia, hypertension, and suffered a cardiac arrest in route to the hospital. |
| **Total** | **94** | |

| Appendix Table 2 – Selected cases for which post-mortem monitoring proved negative | |
|---|---|
| **Case #** | **Circumstances of death, post-mortem findings, toxicology results** |
| **1985-1061** | Post mortem toxicology following an airplane accident showed normal cholinesterase, 0% carboxyhemoglobin, negative blood alcohol, and a negative urine screen for pharmaceuticals and street drugs. The coroner recorded craniocerebral trauma as the cause of death. |
| **1987-001** | A 39-year-old worker collapsed one January afternoon after cleaning up rinse material from chlorpyrifos, malathion, diazinon and chlordane pesticide containers at the offices of a Southern California structural pest control company in the morning. Other materials stored at the site included calcium cyanide and ethylene dibromide. Negative toxicology sample reports from autopsy included: AChE 13.6 U/L (9.9-16.0 U/L reference range), tissue, stomach contents negative for organochlorines and for EDB. Gross pathology showed atherosclerotic coronary disease and evidence of prior myocardial infarctions. |
| **1988-1252** | A 39-year-old worker collapsed in an orchard while operating a mower in vicinity of burn pile possibly contaminated with parathion. Environmental samples showed very patchy distribution of residual parathion (7 soil samples were negative and 2 showed high levels of residue: 29,000 ppm, 38,000 ppm). Blood samples tested at a toxicology laboratory were negative for para-nitrophenol. Testing for ethyl alcohol, carbon monoxide, barbituates and street drugs was negative. A blood sample was sent for measurement of AChE, but the result was not included in the investigation report. |
| **1989-1011** | Murder, suicide. It was reported possible that the perpetrator of a schoolyard shooting had used "Black-leaf 40" (contains nicotine as active ingredient) as stimulant prior to the episode. No direct information available because police/coroner were the lead agency on investigation. Press reports on case indicate that post-mortem monitoring showed only trace levels of caffeine and nicotine. |
| **1990-660** | A 36-year-old flagger developed joint pain, dizziness and headache at work in March. There was no specific exposure incident, but he was hospitalized. Possible OP poisoning was ruled out on 3/20/90: BuChE levels: 2251 U/L (1000-3900 U/L reference); AChE: 9942 U/L (4000-10000 U/L reference). Multiple prior tests also in investigation record (8/24/1989 - 2086 U/L, 10638 U/L; 11/22/1989 - 2497 U/L, 10269 U/L). Baseline taken at an unspecified date was recorded as 2323 U/L , 9824 U/L. Symptoms attributed to vestibular dysfunction and not to work exposure. He was hospitalized on and off prior to his death in August for cholecystectomy, ulcerated colon and congenital heart failure. However, a complete copy of his subsequent hospital records was not included in the case investigation file. |

| Appendix Table 2 – Selected cases for which post-mortem monitoring proved negative | |
|---|---|
| **Case #** | **Circumstances of death, post-mortem findings, toxicology results** |
| **1990-1755** | A 62-year-old flagger began having chest pain and indigestion prior to starting work in August during 90 - 00 degree weather. He was flagging for a methomyl application when he collapsed; BuChE 137% baseline, AChE 99% baseline at autopsy. Brain ChE levels measured at UC Davis reference laboratory were also within normal limits compared to literature reference values and showed no evidence of change with oxime activation. Gross post-mortem examination showed: pulmonary congestion, acute infarction of the interventricular septum, posterior wall of left ventrical; scarring from previous infarctions was also noted, as well as severe coronary atherosclerosis. Records included 12 years of prior ChE monitoring that did not show evidence of AChE, BuChE depression. |
| **1993-1356** | A 48-year-old worker collapsed and died while working as a shoveler at the edge of a field being fumigated with methyl bromide in August. His coworkers reported that he had complained of arm pain several days earlier, but his spouse reported that he had not had any symptoms in the days prior to death. An autopsy blood sample was negative for bromide, but there was almost complete blockage of left anterior descending coronary artery and a corresponding infarction that was at least 24 hours old. |
| **1996-779** | A grower/agricultural pest control operator was found slumped over the steering wheel of his truck. He was taken to a hospital where he was pronounced dead. The coroner determined the cause of death was not related to pesticides; cause of death was coronary artery arteriosclerosis. Autopsy biomonitoring limited to street drugs, ETOH, pharmaceuticals, and positive caffeine. |
| **2004-84** | While sleeping, the girlfriend thought a 27-year-old applicator. who had been applying a chlorpyrifos emulsifiable concentrate, had difficulty breathing and called 911. The paramedics arrived and tried to resuscitate him. They took him to the hospital where the doctor pronounced him dead. Clothing samples showed some contamination with DEF (7.7 mg on coveralls), malathion (1.55 mg on jeans) and chlorpyrifos (2.1 mg on jeans). BuChE levels were normal (2.9 U/ml: reference range 1.80-4.20 U/ml). No detectable malathion or chlorpyrifos was found in the patient's plasma when tested at the same laboratory. Tests for alcohol and street drugs were negative. Post mortem gross pathology showed pulmonary congestion (consistent with terminal asphyxia), but the cause of death was listed as undetermined. |
| **2006-372** | Medical efforts could not revive an abused child who arrived at a hospital without breath or pulse. He reportedly drank a pine oil product. Blood test showed acetone 23 mg/Dl – (major metabolite of isopropanol) and isopropanol 4 mg/Dl. Levels of ispropanol associated with symptomatic illness usually more than 50 mg/Dl. |