Secondhand Pesticides

Airborne Pesticide Drift in California

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One in a series of reports by Californians for Pesticide Reform

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Abbreviations

ARB	California Air Resources Board
CAC	County Agricultural Commissioner
Cal EPA	California Environmental Protection Agency
CDFA	California Department of Food and Agriculture
CIMIS	California Irrigation Management Information System
CPR	Californians for Pesticide Reform
CRLA	California Rural Legal Assistance Inc.
CRLAF	California Rural Legal Assistance Foundation
DHS	California Department of Health Services
DPR	California Department of Pesticide Regulation
ECOSLO	Environmental Center of San Luis Obispo
EWG	Environmental Working Group
FQPA	Federal Food Quality Protection Act of 1996
H_2S	Hydrogen sulfide, a breakdown product of metam sodium
HAP	Hazardous Air Pollutant, as defined by U.S. EPA (see page 47)
HAP-TAC	Hazardous Air Pollutant that is also listed as a California Toxic Air Contaminant
HQ	Hazard Quotient (see pages 22 and 23)
IRED	Interim Reregistration Eligibility Decision
OEHHA	California Office of Environmental Health Hazard Assessment
LOAEL	Lowest Observed Adverse Effect Level (see page 57)
LOD	Limits of Detection (see page 61)
LOEL	Lowest Observed Effect Level (see page 57)
LOQ	Limits of Quantitation (see page 61)
MIC	Methyl isocyanate, a breakdown product of metam sodium
MITC	Methyl isothiocyanate, a breakdown product of metam sodium
NAR	Neighbors at Risk
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No Observed Adverse Effect Level (see page 57)
NOEL	No Observed Effect Level (see page 57)
PAN	Pesticide Action Network
RED	Reregistration Eligibility Decision
REL	Reference Exposure Level (see pages 20 and 23)
RfC	Reference Concentration (see page 23)
SRP	Scientific Review Panel for Toxic Air Contaminants (see page 47)
TAC	Toxic Air Contaminant (see page 47)
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Vp	Vapor pressure (see Table 1-5, page 20)

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Executive Summary

Widespread pesticide drift affects diverse communities across California

New analysis of pesticide drift in this report reveals that several widely used pesticides are regularly found far from their application sites at concentrations that significantly exceed acute and chronic exposure levels deemed "safe" by regulatory agencies. Virtually everywhere pesticides are used, they drift away from their intended target and can persist for days and even months after application. These "secondhand pesticides," like secondhand cigarette smoke, can cause serious adverse health effects and are forced on others against their will. It's time for California agriculture to kick the pesticide habit and for the agencies responsible to take action to protect public health by reducing and eliminating use of drift-prone pesticides.

Secondhand pesticides, like secondhand cigarette smoke, can cause serious adverse health effects and are forced on others against their will.

Pesticide drift is any airborne movement of pesticides (insecticides, herbicides, fungicides, etc.) away from the intended target, including droplets, dusts, volatilized vapor-phase pesticides, and pesticide-contaminated soil particles. Sometimes drift is very noticeable as a cloud of spray droplets or dust during application, or as an unpleasant odor afterwards. But it is frequently insidious—invisible to the eye and odorless—often persisting for days, weeks, or even months after application as volatile chemicals evaporate and contaminate the air.

California leads the U.S. in pesticide use, with more than 315 million pounds of pesticide active ingredients sold in 2000. More than 90% of pesticides used in the state—products used as sprays, dusts, or gaseous fumigants—are prone to drift. In outdoor settings, airborne pesticides are carried away from the application site by wind and on windblown soil particles. Drifting pesticides can travel for miles, resulting in widespread toxic air pollution. In indoor environments, vaporized pesticides can persist for months after an application, concentrating in the air closest to the floor—where children spend more of their time—and on plastic items such as children's toys.

Pesticide drift causes acute poisonings and chronic illness, with children most at risk

Pesticide drift causes many acute poisonings every year. Between 1997 and 2000, drift was responsible for half of all reported agricultural pesticide poisonings related to agricultural pesticide use and a quarter of all reported pesticide poisonings. Many more drift-related poisonings occur but go unreported because victims and their physicians do not associate symptoms with pesticide applications. Physicians may not report the incident or the person affected may not seek or be able to afford medical care.

Acute poisonings are not the only problem. Exposures to airborne pesticides at levels below those that create poisoning symptoms are far more common and affect many more people. Like exposure to secondhand cigarette smoke, exposure to airborne pesticides may not necessarily make a person feel sick at the time, but can lead to increased incidence of any number of chronic diseases. Studies on the association of chronic disease with pesticide exposures in both humans and laboratory animals suggest that pesticides can cause or contribute to asthma and other respiratory ailments, various types of cancer, neurological disorders, birth defects, miscarriages, and sterility.

Children are more vulnerable to ill effects from pesticides than adults because their bodies are still growing and developing, and their ability to detoxify chemicals is limited. Their exposures to pesticides from all pathways (food, water, air, other) are likely to be higher, because they eat more food, drink more water, and breathe more air per pound of body weight. Exposures early in life can cause impaired growth and development, cancers, and lifelong disabilities.

Hundreds of thousands of Californians are at risk from pesticide drift

Analysis of pesticide air monitoring results and pesticide use data indicates that hundreds of thousands of Californians live where they are at risk of ill health from pesticide drift (see Chapter 1). Due to their occupation, farmers and farmworkers are the most highly exposed groups, but urban and suburban residents are also vulnerable. In urban areas, people are exposed through building fumigations and pesticide applications in homes, yards, and gardens. Those who live in suburbs on the agricultural–urban interface or who live or work in agricultural communities face high exposures from agricultural pesticide applications. Children who live or attend school near farmland are particularly vulnerable. Organic farmers suffer economic loss when they cannot market their crops as "certified organic" due to pesticide drift from neighboring farms. Airborne pesticides also impact ecosystems, both adjacent to and quite distant from application sites.

Pesticide concentrations in air frequently exceed levels of health concern

New analysis presented in this report shows that Californians are routinely exposed to concentrations of pesticides in air that exceed levels of health concern, often by large margins. Chapter 2 compares concentrations of pesticides found in air after legal agricultural pesticide applications to Reference Exposure Levels (RELs)—concentrations the U.S. Environmental Protection Agency (U.S. EPA) or the California Department of Pesticide Regulation (DPR) deem unlikely to cause ill effects. We found that concentrations in air, both near and far from application sites, exceeded RELs for most chemicals evaluated for acute (short-term), sub-chronic (intermediate term), and chronic (long-term) exposures.

This report examines air monitoring data collected by DPR and the California Air Resources Board (ARB) for agricultural uses of the fumigants methyl bromide, metam sodium/methyl isothiocyanate (MITC), and 1,3-dichloropropene (Telone); the insecticides diazinon and chlorpyrifos; and the herbicide molinate. Near application sites (within 30–500 feet), pesticide air concentrations exceeded acute RELs for MITC, chlorpyrifos, and diazinon for adults and children, and molinate for children (see Figure A). Ambient, seasonal concentrations in areas of high use but not adjacent to an application site surpassed sub-chronic RELs for methyl bromide and MITC for adults and children, and for chlorpyrifos, diazinon, and molinate for children (see Figure B). Chronic exposures to Telone projected from current use levels would substantially exceed the "acceptable" cancer risk of one in one million in high-use areas if use continues at the current level. The maps on page 26 show the distribution of use for these pesticides.

One further caveat remains. The levels determined to be "acceptable" by U.S. EPA and DPR are unlikely to be fully health-protective. With a few exceptions, U.S. EPA and DPR evaluate pesticide toxicity and determine "acceptable" risk by evaluating risk from exposure to only one pesticide in isolation from any other toxicants. However, monitoring data show that simultaneous exposures to multiple pesticides and other toxicants are common. It is unlikely

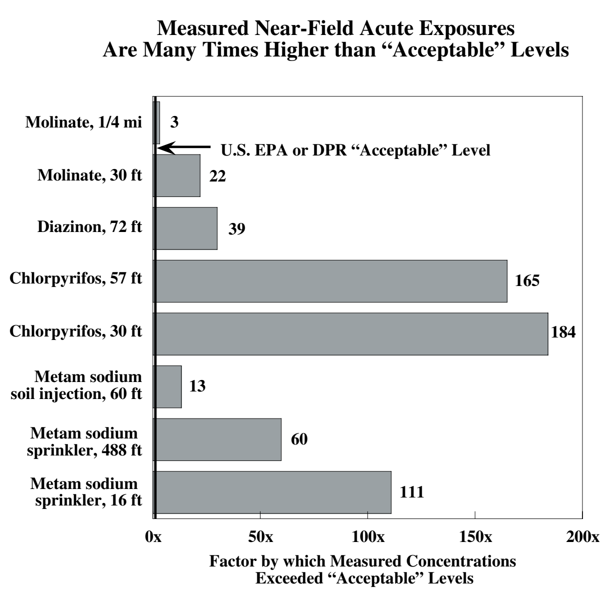

Figure A

Acute, near-field concentrations of most pesticides evaluated exceeded "acceptable" levels for both children and adults. In this plot, the bars represent the factor by which the measured concentrations exceed the acute Reference Exposure Level (REL) for a one-year-old child.
Source: see Chapter 2.

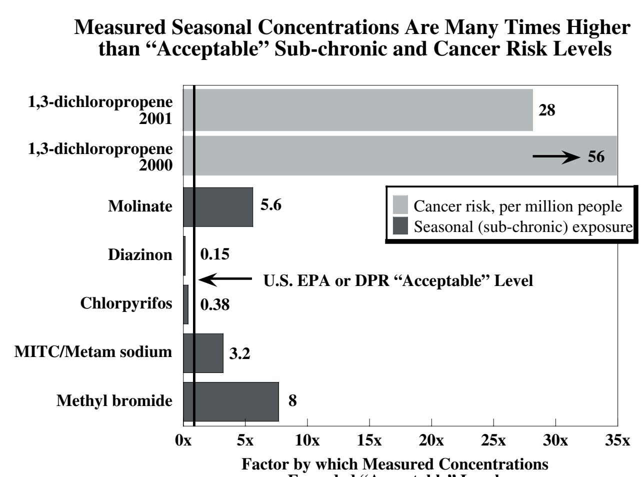

Figure B

Seasonal exposures to pesticides in ambient air pose both cancer and non-cancer risks. In this plot, the dark bars represent the factor by which the measured concentrations of each pesticide in air exceed the sub-chronic Reference Exposure Level (REL) for a one-year-old child. Cancer risk (light bars) only applies to 1,3-dichloropropene (Telone) and is given as a probability of the number of cancers expected per million people from exposure to the chemical at the measured levels over a lifetime. A cancer risk above one in one million is a level of concern.
Source: see Chapter 2.

that exposures to multiple chemicals cause *fewer* health effects than exposure to a single chemical. In fact, the opposite is more likely, and additive or even synergistic effects can reasonably be anticipated. There are many other reasons RELs determined by U.S. EPA and DPR may be under-protective of human health. These include toxicity data gaps for many types of adverse effects, use of uncertainty factors that do not reflect the real differences in susceptibility to toxic effects between humans and laboratory animals or between different individuals, and the undue influence of pesticide manufacturers and users on agencies conducting risk assessments. That the "acceptable" exposure to a single pesticide, or even a class of pesticides with a similar mechanism of action, is determined by such a flawed and unscientific process is far from reassuring.

Use of fumigant pesticides results in many acute poisonings and high seasonal exposures

The fumigant pesticides methyl bromide, metam sodium/MITC, and Telone pose the greatest risk of health effects from pesticide drift in California. Their major use is as pre-plant soil sterilants for a wide variety of crops, most notably strawberries, tomatoes, carrots, and potatoes. Application is particularly high in the Central and South-Central Coast regions; Kern, Merced, and Fresno counties; and in Riverside and Imperial counties in the southeast.

Seasonal, ambient air monitoring studies in 2000 and 2001 in areas of high methyl bromide use but not near any single application showed air concentrations exceeding the sub-chronic child REL by up to a factor of 8. No studies using reliable monitoring techniques are available to evaluate near-field exposures of methyl bromide under current use conditions.

Highly acutely toxic MITC/metam sodium has been responsible for multiple serious pesticide poisoning emergencies. In the Central Valley, neighborhoods in Earlimart in November 1999 and Arvin in July 2002 were downwind of large applications of this pesticide. In Earlimart 173 people and in Arvin over 260 suffered burning eyes, nausea, headaches, dizziness, and vomiting. Over three years later, Earlimart residents are still experiencing effects from the poisoning. Monitoring studies indicate that even seasonal (sub-chronic) concentrations of MITC exceed levels of concern by up to a factor of 3.2 for a one-year-old child.

The major hazard associated with the fumigant Telone is increased cancer risk in high-use areas. Telone was banned in 1990 after air sampling revealed concentrations near Merced County application sites that posed unacceptable cancer risks. However, the chemical was reintroduced in 1995, and use has continued to increase, resulting in increased exposures and correspondingly higher cancer risk. In Kern County, lifetime cancer risks from exposure to average Telone concentrations measured in ambient air in 2000 ranged from 5 to 52 per million, far in excess of the "acceptable" cancer risk of one in one million.

Neurotoxic insecticides pose a particular health hazard for children

Two commonly used insecticides, diazinon and chlorpyrifos, are particularly hazardous to children. Where studies have been done, evidence from laboratory animals shows that early-life exposure to low doses of this class of chemicals reduces development of neural connections. U.S. EPA is phasing out home use of both chlorpyrifos and diazinon because of their hazards to children, but most agricultural uses like those monitored by ARB are not affected. High exposures thus remain likely for those living in or near agricultural communities. Fresno, Monterey, Kern, and Imperial counties report the highest agricultural use of diazinon, and Fresno, Kern, Tulare, and Kings counties the highest agricultural use of chlorpyrifos.

Air monitoring of these two pesticides demonstrates that people living near application sites are exposed to levels that exceed acute RELs for both adults and children. For diazinon, the peak concentration measured 72 feet from the field boundary was 16 times higher than the adult acute REL and 39 times higher than the acute child REL. For chlorpyrifos, the peak concentration measured 30 feet from the field boundary was 8 times higher than the adult acute REL and 184 times higher than the child acute REL.

Sacramento Valley air contains rice herbicide linked to testicular damage and developmental neurotoxicity

Molinate, an herbicide applied almost exclusively to rice, is heavily used in the Sacramento Valley. U.S. EPA's preliminary risk assessment identifies it as a reproductive toxicant, neurotoxicant, and possible carcinogen. Developmental neurotoxicity is a concern for children. Air monitoring near an application of molinate to a Colusa County rice field showed the peak concentration 30 feet from the field boundary to be approximately equal to the adult acute REL and 22 times higher than the child acute REL. The concentration 75 feet downwind of the field at the end of the four-day monitoring period was five times the child acute REL.

Seasonal (sub-chronic) molinate exposures were estimated by measuring air concentrations in the Colusa County towns of Williams and Maxwell, somewhat distant from direct applications but in a region of high use. Over a nine-day period, average measured levels of molinate in air were about one-fourth of the adult sub-chronic REL and 5.6 times the one-year-old child sub-chronic REL. It is important to note that Maxwell and Williams are on the west side of the Sacramento Valley, approximately 25 miles from the area of highest molinate use. Seasonal concentrations are likely to be substantially higher in areas of higher molinate use.

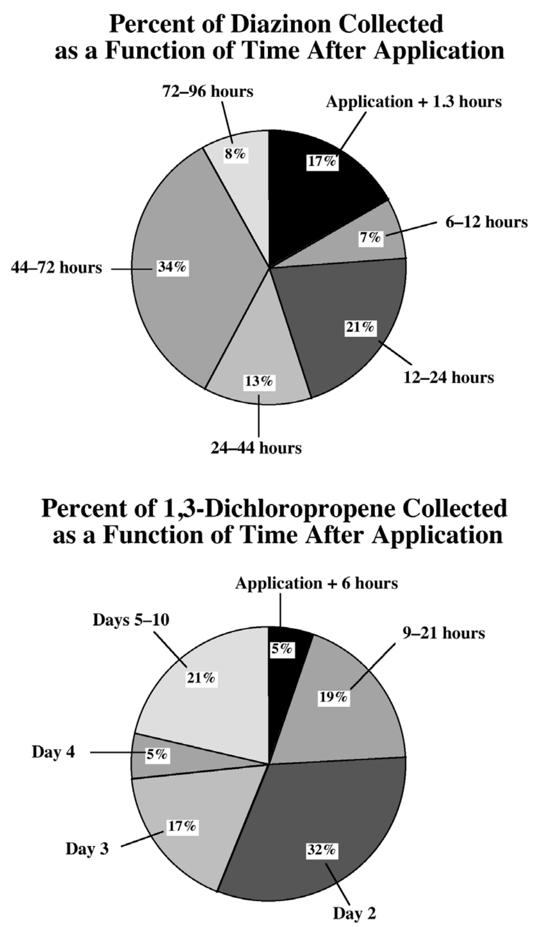

Figure C

For volatile pesticides (about 45% of the total pounds applied in California), most drift occurs long after application is complete. These graphs show the amount of pesticide drift from a treated field during and after application for two volatile pesticides, diazinon (72 feet from the field boundary) and 1,3-dichloropropene (300 feet). Current drift controls only apply to spray drift that occurs during and immediately after application, the black wedge of the pie. See Appendices 2 and 3 for calculations, methods, raw data and data sources.

Present and proposed regulatory strategies do not protect public health and the environment

Air monitoring data clearly show that pesticide concentrations in air exceed levels considered "safe" by regulatory agencies even when pesticides are applied according to label directions. Yet neither U.S. EPA nor DPR are taking sufficient action to protect people from secondhand pesticides. Chapter 3 examines U.S. EPA and DPR approaches for regulating both spray drift and post-application drift, and shows just how badly our regulatory agencies are failing to protect public health and the environment from toxic pesticide air pollution.

Regulatory definition of drift ignores 80-95% of total drift for volatile pesticides

The most obvious flaw in both U.S. EPA and DPR regulatory processes for controlling drift is an overly narrow definition of drift that fails to include all forms of drift, and in some cases includes less than 5% of the total amount of off-site airborne pesticide drift (see Figure C). U.S. EPA and DPR currently define drift as the airborne, off-site movement of pesticides that occurs *during and immediately after a pesticide application.* Yet our detailed analysis of monitoring data shows that, for about 45% of total pesticides applied in California, the bulk of off-site pesticide movement occurs as the pesticide volatilizes (evaporates) after application. ARB monitoring data show that concentrations of pesticides in air peak between eight and 24 hours after the start of application, with concentrations declining over several days to several weeks.

Data presented in this report make it clear that while controls at the time of application are necessary to reduce application-related spray drift, such measures are not sufficient to control post-application drift of volatile pesticides. To adequately address the full range of adverse effects caused by drift, post-application drift must be regulated as well as drift that occurs during applications.

Spray drift controls are ineffective

Present label language on pesticide products does not adequately control spray drift that occurs during applications. In 2000, U.S. EPA began the process of making labels more consistent across all products and initially took a health-protective approach in proposing a label statement that prohibits drift from contacting people, structures people occupy and the associated property, and other non-target sites. Unfortunately, the agency introduced gaping ambiguity in the language by allowing that some undefined low level of spray drift was inevitable and acceptable.

Despite the limited scope of U.S. EPA proposed label language, pesticide applicators, growers, and pesticide manufacturers oppose it. Applicators argue that they cannot do their jobs unless they are allowed to contaminate other people's property, non-target animals, and/or water bodies. Growers, applicators, and industry representatives are lobbying for language that would only prohibit drift that causes "unreasonable adverse effects," leaving one to wonder what, exactly, constitutes a *reasonable* adverse effect. As of March 2003, U.S. EPA has not made a final decision on the label language it will use. However, if the agency is serious about protecting human health, it *must* prohibit any chemical trespass and empower those who enforce the laws to prevent drift and prosecute violators.

In California, new spray drift control proposals take one step forward by expanding specific drift regulations to cover all liquid pesticides, but do not address drift from dusts or fumigant applications.

Unfortunately, both U.S. EPA and DPR approaches to spray drift control focus on technical specifications such as spray droplet size and minimum and maximum allowable wind speeds, most of which would be extremely difficult to enforce. The fact that acute poisonings still occur with disturbing regularity suggests that such minor technology enhancements simply will not suffice. Sub-acute or chronic poisonings from spray drift are likely to be even more common than acute poisonings, but no label language addresses these exposures. Finally, proposed regulatory controls fail to address the fundamental problems of intensive use of highly volatile pesticides, and do not even attempt to reduce post-application drift.

U.S. EPA does not regulate most post-application drift

U.S. EPA is required to assess *all* routes of pesticide exposure (food, water, air, and other) when it re-evaluates a pesticide. However, it routinely dismisses secondhand exposures from post-application drift as unimportant for non-fumigant pesticides, even though it has not yet evaluated California's extensive set of air monitoring data that demonstrates the scope of the problem. Even for the highly volatile fumigants, risks from vapor drift have only been evaluated for a single pesticide, Telone. U.S. EPA has not assessed residential, or "bystander," exposure for people living near application sites for any other pesticides evaluated in this report. And, instead of investing in non-chemical pest controls, the agency is considering the introduction of yet another highly drift-prone fumigant, methyl iodide, as a replacement for methyl bromide, most uses of which are due to be phased out by 2005.

California Department of Pesticide Regulation does not enforce the Toxic Air Contaminant Act

In 1983, the California legislature passed the Toxic Air Contaminant Act to deal with problems of toxic substances in air, including pesticides. As a result, DPR is required to prioritize pesticides for evaluation and work with other departments in the California Environmental Protection Agency (Cal EPA) to obtain monitoring data, assess risks of pesticide exposures, and list problem chemicals as Toxic Air Contaminants (TACs). All of these activities are subject to oversight by an external Scientific Review Panel (SRP) and are open to public comment.

In 19 years, ARB and the California Office of Environmental Health Hazard Assessment (OEHHA) have listed over 200 industrial chemicals as TACs. During the same period, DPR listed only four pesticides. Then, in November 2002, DPR retreated from even this minimal participation in the TAC process, declaring it would meet all of its risk assessment mandates by developing a single process to assess risks across a variety of exposure routes including food, drinking water, and air. This unilateral reorganization of the DPR risk assessment process fails to prioritize pesticides based on their toxicity and potential to be emitted to the air and severely compromises the public's right to know how decisions are made and involvement in the process. It also restricts the SRP peer review role to evaluating only those pesticides that DPR decides to designate as probable TACs. DPR's historical systematic bias against taking the most health-protective measures makes it difficult to believe that decisions made behind closed doors and out of the light of public scrutiny and peer review will sufficiently protect human health.

The final step in the TAC process requires DPR to reduce risk of exposure from chemicals listed as TACs—ethyl parathion, methyl parathion, tribufos (DEF), and MITC (including MITC-generating compounds such as metam sodium and dazomet). To date, just one TAC pesticide (ethyl parathion) has been cancelled, an action prompted mainly by the high risk of worker poisonings. DPR has instituted no new restrictions for tribufos (a cotton defoliant) and methyl parathion (an insecticide). For the most recently listed pesticides—MITC and MITC-generating compounds—DPR is in the process of creating new guidelines. Initial indications are that DPR plans to regulate only exposures that cause acute symptoms of poisoning and will not take into account the health effects of longer-term and/or lower level exposures, thus ensuring their actions will fall short of adequately protecting public and worker health (see Chapter 3).

Pesticides that U.S. EPA lists as Hazardous Air Pollutants (HAPs) under the Clean Air Act are also included under California law as TACs, dubbed HAP-TACs. Of the 41 HAP-TACs registered for use in California, DPR has begun the process of increasing restrictions for only a single pesticide—methyl bromide—and then only because the agency was sued for inaction. New methyl bromide regulations only address excessive acute exposures, even though repeated air monitoring shows ambient air concentrations above sub-chronic levels of concern in high-use areas. In its latest attempt to avoid the obligation to reduce sub-chronic methyl bromide exposures, DPR is proposing to relax the sub-chronic REL for methyl bromide from 1 part per billion (ppb) to 9 ppb for children and 2 ppb to 16 ppb for adults, based on a new industry-sponsored study carried out under conditions that leave serious questions about the validity of the results. OEHHA has taken the position that the REL should remain at 1 ppb (see Chapter 3). This controversy was unresolved when this report went to press. For another major-use HAP-TAC pesticide, Telone, DPR has changed the conditions of use to allow *more use* with *fewer* restrictions since 1995.

Recommendations

Farmers, pesticide applicators, governments, and politicians must fundamentally change how pesticides are used to prevent toxic air pollution on such a grand scale. Minor fixes to existing regulatory controls will not suffice. Instead, a change of mindset and evaluation of the problem from a different point of view are required to address pesticide drift. It is time for U.S. EPA and DPR to create real solutions that truly protect human health and the environment from pesticide drift.

We call on U.S. EPA and DPR to phase out the most hazardous, drift-prone pesticides and pesticide application methods, and to create strong, effective, and enforceable drift laws and regulations that protect everyone, including the most vulnearble population—children. We recommend the following specific actions, discussed in greater detail in Chapter 4.

At both the state and federal levels

Actions that both U.S. EPA and California DPR should take include:

- Phase out use of highly toxic, high-use fumigant pesticides.
- Assist growers in the transition to less-toxic alternatives.
- Define pesticide drift to include all airborne, off-site movement of pesticides.
- Design easily enforceable drift controls that are effective in preventing all drift.
- Require buffer zones, posting and notification for all pesticide applications.
- Consult with affected communities and regulate to protect them.
- Require pesticide manufacturers to fund air monitoring as a condition of continued registration.
- Prohibit introduction of methyl iodide as a methyl bromide replacement.

In California

Within California, DPR must:

- Implement and enforce the Toxic Air Contaminant Act.
- Work with County Agricultural Commissioners to increase fines and improve enforcement of existing regulations.
- Work with County Agricultural Commissioners to establish and implement a uniform pesticide poisoning response protocol.

At the federal level

As the agency primarily responsible for pesticide regulation at the national level, U.S. EPA must:

- Maintain a no-drift standard in pesticide label language.
- Include airborne pesticide exposures in pesticide risk assessments for all pesticides.
- Reduce allowable application rates.
- Issue new regulations under the Clean Air Act to classify pesticide application sites as “area sources” subject to regulation.

1 Introduction: Widespread Pesticide Drift Affects Diverse Communities Across California

Drift-prone pesticides are widely used in California

California leads the U.S. in pesticide use, with more than 315 million pounds of pesticide active ingredients sold in 2000.[1] A total of 188 million pounds were reported used that same year through the California Pesticide Use Reporting (PUR) system.[2] More than 90% of pesticides used in the state are prone to drift because they are used as sprays, dusts, or gaseous fumigants.[3]

Pesticide drift is any airborne movement of pesticides away from the intended target site, including droplets, dusts, volatilized vapor-phase pesticides, and pesticide-contaminated soil particles. Drift can occur both during and for many days, weeks, and even months after pesticide application. It can be very noticeable as a cloud of pesticide spray or dust or an unpleasant odor during the application. It can also be insidious—invisible to the eye, undetectable to the nose, but still capable of causing illness. As with secondhand cigarette smoke, these secondhand pesticides can cause significant adverse health impacts even at low levels. Drift is forced on others against their will and often without their knowledge.

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In outdoor settings, airborne pesticides are carried away from the application site by wind and on windblown soil particles that contaminate the air of homes, yards, workplaces, and parks and are deposited on surfaces that people come in contact with. Drifting pesticides can travel for miles, resulting in widespread toxic air pollution. In indoor environments away from sunlight, vaporized pesticides can persist for weeks or months after application, in a cycle of evaporation and condensation that concentrates residues on plastic items such as children's toys and other synthetic materials.[4]

A significant fraction of pesticides used in California are highly toxic to humans, capable of causing acute poisoning, cancer, birth defects, sterility, neurotoxicity, and/or damage to the developing child. Of 188 million pounds of pesticides reported used in 2000, 70 million (34%) meet one or more of these criteria and thus fall in the category of "Bad Actor" pesticides (see page 8). In 1997 in California, pesticides accounted for the release of 4.9 times more toxic materials to the environment than manufacturing, mining, or refining facilities (see Figure 1-1).[5] Nationwide that year, pesticides constituted nearly one-third of total toxic emissions to the environment.[6]

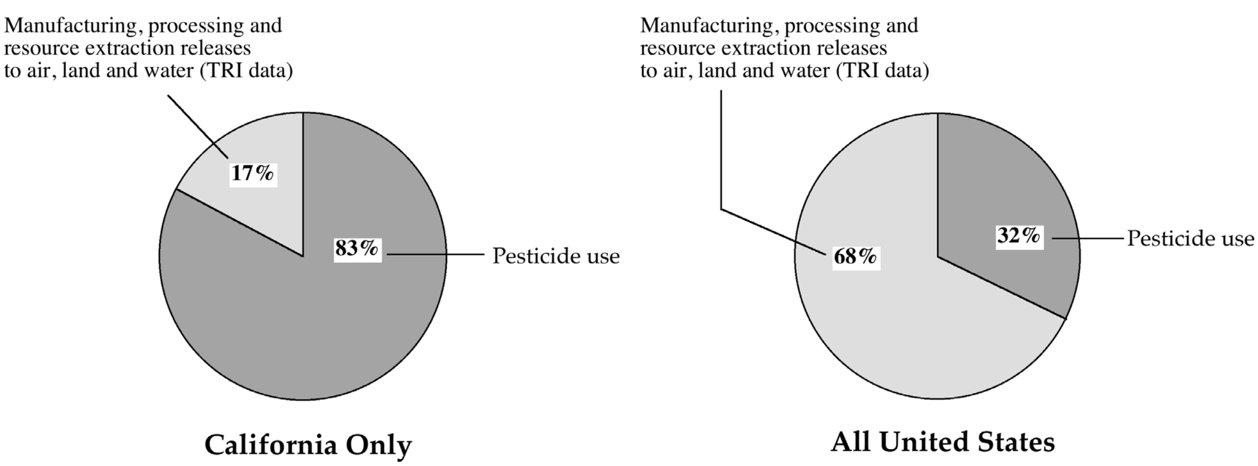


Figure 1-1
Comparison of Toxic Release Inventory to estimated pesticide active ingredient use in 1997 for all U.S. and the state of California, a state with a significant amount of agricultural pesticide use.
Sources: Reference 6.

California Bad Actor Pesticides

To identify the most-toxic pesticides, Californians for Pesticide Reform (CPR) uses the term "Bad Actor." Such pesticides are registered for use in California and fall into one or more of the following categories:*

- **Carcinogens:** Pesticides listed as known or probable carcinogens by U.S. EPA, the International Agency for Research on Cancer, or the State of California.
- **Reproductive and developmental toxicants:** Pesticides known to cause infertility, sterility, birth defects, and impaired childhood development, listed by the State of California or U.S. EPA.
- **Pesticides with high acute toxicity:** Pesticide active ingredients that are acute systemic poisons. These materials are lethal to laboratory animals when they ingest less than 50 mg per 1 kg of body weight, inhale air containing a concentration of the substance less than 0.2 mg per liter of air, or are exposed through the skin to levels less than 200 mg per kg of body weight. In other words, for a 150-pound person, consumption of as little as one-tenth of an ounce can be fatal.
- **Cholinesterase inhibitors:** Neurotoxic pesticides known to interfere with proper functioning of cholinesterase (ChE), an enzyme necessary for proper transmission of nerve impulses. Two chemical classes of pesticides—organophosphorus and carbamate compounds—comprise the ChE-inhibiting pesticides. The list of ChE inhibitors was constructed based on DPR's list of ChE-inhibiting pesticides.
- **Groundwater contaminants:** Pesticides found repeatedly in groundwater in California. State law severely restricts their use in designated areas susceptible to groundwater contamination.

Other Pesticides of Concern

- **Endocrine disruptors:** Pesticides linked to the disruption of hormone function in humans and/or wildlife. These chemicals have been shown to alter levels of male and female hormones, as well as certain thyroid hormones. While it is clear that some pesticides are capable of having endocrine disrupting effects, no comprehensive list of endocrine-disrupting pesticides has yet been compiled. We designate a pesticide as an endocrine disruptor based on multiple data sources. Because insufficient information exists on these chemicals to determine the extent of potential harm they might cause, designation of a pesticide as an endocrine disruptor alone does not place it on the list of CA Bad Actor pesticides.
- **Restricted use pesticides (RUPs):** Both U.S. EPA and the State of California restrict use of some pesticide products because they are acutely toxic to humans or beneficial insects; have been shown to cause worker illnesses, groundwater contamination, or bird or fish kills; or their drift damages other crops. RUPs can be used only by state certified and licensed applicators, and then only under specific conditions.
- **Respiratory irritants and sensitizers:** Many pesticides are irritating to the respiratory tract, causing chest tightness, difficulty breathing, coughing, and a burning feeling in the lungs. Some pesticides can cause asthma, and others trigger attacks for those who already have the disease. Sensitization also occurs with exposure to certain pesticides, which means that once a person is exposed to the chemical, the body manufactures antibodies against it; afterward, very small amounts of the pesticide can cause a serious adverse reaction. This process is similar to the sensitization of individuals to the toxic ingredient in poison oak.

* For sources of toxicity information, see S. Kegley, *PAN Chemicals of Concern* and references therein, Pesticide Action Network Pesticide Database Documentation, http://docs.pesticideinfo.org/documentation4/ref_toxicity7.html#BadActor.

Exposure to secondhand pesticides causes adverse health effects

Just as smokers have a higher risk of getting lung cancer, emphysema, and heart disease than non-smokers, studies show that people who regularly work with pesticides have a significantly elevated risk of certain types of cancer, neurological disorders, respiratory disease, miscarriages and infertility relative to a control group with less pesticide exposure. But exposure to volatile pesticides is not limited to workers. The ability of pesticides to drift away from where they are applied ensures secondhand exposure opportunities for those who just happen to be in the area, through breathing pesticide-contaminated air or dust and contact with surfaces contaminated by residues resulting from pesticide drift.

The ability of pesticides to drift away from where they are applied ensures secondhand exposure opportunities for those who just happen to be in the area.

Pesticide drift causes acute poisonings

Drift incidents like those highlighted in Chapter 2 and documented in the California Pesticide Illness Surveillance Program (PISP) database[7] result in many people being sent to the hospital with symptoms of acute poisoning (Table 1-1). In California between 1997 and 2000, drift accounted for approximately half of all reported poisonings related to agricultural pesticide use and for 26% of all reported pesticide poisonings.[8] But pesticide incident reports show only the tip of the iceberg in terms of the numbers actually poisoned. These reports do not capture the countless people who are exposed to secondhand pesticides but either are not aware of the exposure or do not know how to report it. Because notification is not required for most pesticide applications, affected people and their physicians are generally not aware of when pesticide applications might play a role in their ill health. Even if a physician were to correctly identify a poisoning, he or she might not report the incident, or the person affected might not seek or be able to afford medical care. Combined with the fact that symptoms often mimic a cold, flu, or food poisoning, it is easy to see why statistics miss many pesticide poisonings.

Table 1-1: Health Effects of Six Drift-Prone Pesticides

Pesticide	Symptoms of Acute Exposure	Other Known Health Effects[a]
Methyl bromide	Irritation of skin, eye, nose, throat, respiratory tract. Exposure may result in fluid in the lungs and neurological effects. The central nervous system, liver, and kidneys are target organs.	Birth defects, nervous system and neurobehavioral effects.
MITC/Metam sodium[b]	Irritation of eyes, nose, throat, respiratory tract, shortness of breath, headache, dizziness, nausea, diarrhea.	Metam sodium is a probable carcinogen.
1,3-Dichloropropene (Telone)	Irritation of eyes, headache, chest pain, fatigue, irritability, and difficulty concentrating, the latter persisting for as long as two years after initial exposure.	Probable carcinogen.
Chlorpyrifos	Convulsions, pinpoint pupils, muscle cramps, excessive salivation, dizziness, sweating, nausea, vomiting.	Developmental neurotoxicant and other neurotoxicity, suspected endocrine disruptor.
Diazinon	Irritation of eyes, skin, labored breathing, convulsions, pinpoint pupils, muscle cramps, excessive salivation, dizziness, sweating, nausea, vomiting.	Birth defects, neurotoxicity.
Molinate	Irritation of eyes, respiratory tract, shortness of breath, headache, nausea, dizziness, confusion.	Damage to male reproductive system, possible carcinogen, birth defects, delayed neurotoxicity, suspected endocrine disruptor.

a. See the PAN Pesticide Database for more information on cancer ranking systems and other types of toxicity, http://docs.pesticideinfo.org/documentation4/ref_toxicity7.html#BadActor.

b. Metam sodium is the applied pesticide that breaks down to the active fumigant MITC.

PAN archive

Spray drift from pesticide applications contaminates waterways as well as air.

"Since yesterday, I have been suffering severe headaches, migraine, nausea, dry nose and sore throat. I believe that the methyl bromide application yesterday caused these symptoms. I have been living in this same house for the last fourteen years. Every year at this time, I experience the same symptoms. I did not visit the doctor because I cannot afford it."
— Oceano resident, October 1, 2001.[9]

Note: This resident's house was about 1,500 feet from the pesticide application. The required buffer zone was only 70 feet. Despite obvious symptoms, an investigation concluded no regulations were violated, highlighting the problem that even legal pesticide applications can result in poisonings.


PAN archive

Chronic illnesses are linked to pesticide drift

Acute illness from drift is not easy to conceal, especially when it involves communities and large numbers of farmworkers as documented in this volume. But most pesticide drift is silent, and unknown to the general public. Most drift exposures are from legal pesticide use that does not result in apparent illness, leading to false assumptions of safety. The most worrisome health problems are long-term effects that do not show up until months or years later—too late to identify the source or do anything about the exposure. These chronic effects include cancer in children and adults, and reproductive and neurological problems, among others.

Most drift exposures are from legal pesticide use that does not result in apparent illness, leading to false assumptions of safety.

Most studies of chronic health effects of pesticides are of people exposed to pesticides in the workplace, such as farmers, farmworkers, exterminators, and pesticide formulators and factory workers. Non-occupational and environmental exposures are more relevant to health risks from exposure to drift. This discussion summarizes risks from living near crop growing areas or factories emitting airborne pesticides, or from home and community exposures. The summary does not include direct contact occupational exposures or accidental or suicidal ingestion.

The developing fetus, infants, and young children are the most vulnerable to chronic health effects from drift.

The developing fetus, infants, and young children are the most vulnerable to chronic health effects from drift. They clearly do not bring on the exposure themselves and are affected by exposures not toxicologically significant in an adult. The amount of time between exposure and adverse chronic effects is much shorter in children. They are unlikely to have other exposures (e.g. alcohol, tobacco, prescription/recreational drugs) that can make adverse health effects more difficult to study in adults. However, adults are also vulnerable, as shown in studies cited in the text and tables that follow.

Pesticide Effects in Humans
1. Acute effects
2. Chronic effects
3. Worsening of pre-existing diseases and conditions

Tables 1-2 and 1-3 (pp. 12–13) summarize selected studies of chronic effects of pesticides with statistically significant findings. (See Appendix 1 for an explanation of the studies and information on how to interpret the numbers and ratios in the tables). The tables list studies chronologically by country of origin. Many factors not discussed in this summary can affect findings. See citations in the reference section for full details of each study.

Cancer in Children: Pesticides are a risk factor for several types of cancer in children. Among the highest is parents' home pesticide use, which can increase the risk of leukemia more than 11 times (1,100%)[10] and brain cancer more than 10 times (1,080%).[11] Home extermination increases the risk of non-Hodgkin lymphoma,[12] leukemia,[13] and Wilm's tumor.[14] Living on a farm increases the risk of bone cancer[15] and leukemia.[16, 17] Having parents who are farmers or farmworkers increases the risk of bone cancer,[15, 18, 19, 20] brain cancer,[21] soft tissue sarcoma,[22] and Wilm's tumor.[23]

Cancer in Adults: For adults, living in a crop production area where pesticides are used increases the risk of non-Hodgkin lymphoma,[24–27] leukemia,[24–26, 28] brain cancer,[24, 29, 30] nasal cancer,[31] ovarian cancer,[32, 33] pancreatic cancer,[34] rectal cancer in males,[34] soft tissue sarcoma,[27, 35] stomach cancer,[34, 36] and thyroid cancer in males.[31, 34] There is a study showing an increase in risk of soft tissue sarcoma and thyroid cancer in men living near a factory emitting an airborne pesticide.[37]

Birth Defects: Effects on reproduction are difficult to study since the mother, the father and the developing child are all at risk. Most birth defect studies are of women exposed at work during pregnancy, or men occupationally exposed. Being pregnant and living in a high pesticide use area increases the risk of cleft lip/palate,[38] limb reduction defects,[39] and neural tube defects (spina bifida, anencephaly),[40] and any type of birth defect.[40–43] Even if the mother is not exposed to pesticides, the father's work in agriculture can increase the risk of cleft lip/palate,[40] hypospadias, or any type of birth defect.[43–45]

Stillbirth: Environmental pesticide exposure can increase the risk of babies born dead (stillbirth). Mothers living in areas of pesticide use[42, 46, 47] or near a pesticide factory,[48] or using pesticides in the home[49, 50] are at increased risk.

Spontaneous Abortion (miscarriage): Many pesticides are embryotoxic or fetotoxic in animals, increasing the risk of early death of the embryo or fetus in humans. A high percentage of normal human conceptions end in spontaneous abortion, making it difficult to study the impacts of environmental toxicants. A heavy menstrual period or an occasional missed period may not be recognized, let alone documented, as a spontaneous abortion. Increase in risk was found in two well-known incidents of community exposure: the ingestion of seed wheat treated with hexachlorobenzene in Turkey in the 1950s,[51] and a factory accident in Bhopal, India.[52] Several studies show an increase in risk if the father, not the mother, is exposed to pesticides in floriculture,[53] in cotton fields,[54] or as an agricultural applicator.[55, 56]

Fertility: There has been much interest in the effects of pesticides on fertility, especially sperm counts. Available human pesticide studies relate only to occupationally exposed workers. There are none relevant to drift exposures.

Neurological Disease: Most pesticides are neurotoxic and can damage the brain and nerves. The neurological disease most often linked to pesticide exposure is Parkinson's disease, a disorder of a specific area of the brain (basal ganglia). Most studies in humans are of workers occupationally exposed, especially to herbicides. There are reports of increased risk of Parkinson's disease from home exposure,[57] living in a rural area,[58–66] or using well water.[63, 64, 67–70]

Factors Influencing Health Effects of Drift

1. **Toxicity of the pesticide**
   Includes inert ingredients, contaminants, and other chemicals that may be in the product.
2. **Amount and concentration**
   Includes type of formulation (aerosol, fogger, liquid, spray, dust, bait, etc.), particle size, volatility, half-life, and other characteristics.
3. **Type and duration of exposure**
   Includes swallowing (ingestion), breathing in (inhalation), skin (dermal absorption), or some combination. The skin is the most important route for most pesticides.
4. **Who is exposed**
   Includes the fetus, infants, toddlers, pregnant women, children, elderly, those with asthma, allergies, or chemical sensitivity, and the immunocompromised.

However several studies also report decreased risk or no association with rural residence[71] or well water use.[71c, 72] An emerging area of research is investigation of pesticides as a risk factor for other neurological diseases such as multiple system atrophy,[73] amyotrophic lateral sclerosis (ALS, Lou Gehrig's disease),[74] and Alzheimer's dementia.[75] There are no studies of pesticides as a risk factor for developmental disabilities in children such as autism, cerebral palsy, and severe mental retardation, although research interest is increasing.


Jason Malinsky

Children who live on a farm have increased risk of some cancers.

Table 1-2: Cancer in Children and Adults: Pesticide Drift from Environmental, Home, Garden, and Other Sources

(See Appendix 1 for information on using this table)

Cancer in Children		Cancer in Adults	
Location and Source of Exposure	Ratio	Location and Source of Exposure	Ratio
Bone Cancer		**Brain Cancer**	
Australia/father a farmer[15]	OR 3.5 bs*	Canada Quebec/live in high pesticide use area[24]	Increase
Child lived on a farm	OR 1.6 bs*	Spain/live near factory emitting HCB[c]—males[37]	SIR 2.7 bs*
Canada/mother exposed to farm pesticides[18]	OR 7.8	Sweden/live in high farm pesticide use area[29]	OR 2.4 bs*
Norway/farmer parents[19]	RR 2.9	U.S. Cape Cod/live near cranberry bog—females[30]	OR 6.7
U.S. California/father an agricultural worker[20]	OR 8.8	**Leukemia**	
Brain Cancer		Australia/live in sugar cane area—females[25]	OR 1.54
France/child lived on a farm[76]	OR 6.7	Canada Quebec/live in pesticide use area[24]	Increase
Home treatment during childhood	OR 2.0 bs*	Italy/flower workers' adult children[77]	Increase
Germany/wood preservative exposure[78]	OR 1.91	Philippines/live in rice crop area—males[28]	SMR 4.8
Norway/farmer parents[19]	OR 2.36	U.S. Michigan/live in pesticide use areas[26]	SIR 1.4
Sweden/parents exposed to pesticides[21]	OR 4.0	**Malignant Melanoma—Skin**	
U.S./child lived on a farm[16]	OR 3.8[a]	U.S. Georgia/personal pesticide use (survey)[27]	OR 3.6 bs*
U.S. California-LA/home flea/tick sprays/foggers[11]	OR 10.8	**Nasal/Sinonasal Cancer**	
U.S. Denver/home pest strip use[12]	OR 1.8	Philippines/insecticide coil burning[79]	OR 7.8
U.S. Missouri/home aerosol bombs/foggers[80]	OR 6.2	U.S. Minnesota/live in pesticide area—females[85]	SRR 3.35
U.S.-Canada[b]/child lived on farm 1 yr or more[17]	OR 5.0	**Non-Hodgkin Lymphoma**	
Leukemia		Australia/live in sugar cane area—females[25]	SMR 1.54
England/Wales/mother propoxur mosquito spray[81]	OR 9.7	Canada Quebec/live in pesticide use area[24]	RR 1.6-3.7
Germany (West)/home garden use[82]	OR 2.5 bs*	Italy/live in rice growing area—males, females[31]	RR 2.1, 1.3
U.S. California/prenatal professional extermination[13]	OR 2.8	U.S. California/2 firemen[83]	Case report
U.S. California-LA/home garden use by mother[84]	OR 9.0	U.S. Minnesota/live in wheat crop area—females[85]	SRR 1.35
Garden use either parent once a month	OR 6.5	U.S. Iowa/farm women[86]	OR 1.89
Indoor use more than once a week	OR 3.8	U.S. Michigan/live in pesticide areas—males[26]	OR 3.8
U.S. Denver/home pest strip use[12]	OR 3.0	**Ovarian Cancer**	
U.S.-Canada[b]/postnatal rodenticide use[87]	OR 1.8	Italy/flower workers' adult children[77]	SRR 3.35
U.S. St. Jude's Hospital/home garden use[88]	OR 2.1	Italy/live in high atrazine use area[32]	Increase
U.S. California/high propargite use area[89]	OR 1.48	Italy/live in high herbicide use area[33]	RR 4.28
U.S.-Canada[b]/preconception exposure	OR 2.09	**Pancreatic Cancer**	
U.S.-Canada[b]/parents exposed 3 yrs, child 5 yr old or under[10]	OR 11.4	Spain/DDE and K-ras mutation[90]	OR 8.8
Parents exposed 3 yrs, all age children	OR 3.8	U.S. California/DDE levels[91]	Increase
Non-Hodgkin Lymphoma		U.S. Michigan/self-reported ethylan exposure[92]	Increase
Germany/professional home treatment[93]	OR 2.6	U.S. 4 states[d]/live in wheat crop area[34]	Increase
U.S. St. Jude's Hospital/home garden use[87]	p = 0.03	**Prostate Cancer**	
U.S. Denver/home extermination[12]	OR 1.8	Canada Montreal/home use[94]	OR 2.3
U.S.-Canada[b]/frequent home use[95]	OR 7.3	U.S. 4 states[d]/live in wheat crop area[34]	Increase
Neuroblastoma		**Rectal Cancer**	
Norway/farmer parents[19]	RR 2.51	U.S. 4 states[d]/live in wheat crop area—males[34]	Increase
U.S.-Canada[b]/home garden use, child <1 yr old[96]	OR 2.2.	**Soft Tissue Sarcoma**	
U.S. New York/mother exposed to insecticides[97]	OR 2.3	Finland/chlorophenol water[35]	RR 8.9
U.S.-Canada[b]/father a landscaper[98]	OR 2.3 bs*	Italy/live in rice crop area—males[31]	SMR 1.8
Soft Tissue Sarcoma		Spain/live near factory emitting HCB[c]—males[37]	SIR 5.5
U.S. Denver/yard pesticide use[12]	OR 3.9	U.S./self-reported herbicide use[99]	OR 2.9
Italy/mother a farmer[22]	Increase	**Stomach Cancer**	
Testicular Cancer		Hungary/live in high pesticide use area—males[36]	RR 3.20
Norway/farmer parents[19]	SIR 1.25	U.S. 4 states[d]/live in wheat crop area[34]	Increase
Wilm's Tumor		**Thyroid Cancer**	
Brazil/father a farm worker[23]	OR 3.24	Spain/live near factory emitting HCB[c]—males[37]	SIR 6.7
Norway/farmer parents[19]	RR 8.87	U.S. 4 states[d]/live in wheat crop area—males[34]	Increase
U.S.-Canada[b]/home extermination[14]	OR 2.2	U.S. Minnesota/live in pesticide use area—males[85]	SRR 1.1bs*

* bs = borderline significance

a. Nervous system tumors
b. Children's Cancer Study Group: Collaboration between United States (CO, DC, IL, IN, IA, MI, MN, NJ, NY, NC, OH, OR, PA, TN, TX, UT, WI) and Canada (BC, NS, ONT)
c. Hexachlorobenzene
d. Minnesota, Montana, North Dakota, South Dakota
e. Collaborative Perinatal Project, a cohort study of 56,000 pregnancies at 12 medical centers, 1959–1965
f. Hexachlorobenzene-treated seed wheat not meant for human consumption was used to make bread, resulting in a large outbreak of acquired porphyria cutanea tarda
g. Thifensulfuron-methyl, tribenuron-methyl, fenoxaprop-P-ethyl, and MCPA
h. Attributable Risk (% age related to pesticide exposure)
i. National Natality Fetal Mortality Survey, a national probability sample of live births and stillbirths in 1980

Table 1-3: Reproductive and Neurological Effects: Pesticide Drift from Environmental, Home, Garden and Other Sources *(See Appendix 1 for information on using this table)*

Reproductive Outcome Location and Source of Exposure	Ratio
Any Birth Defect	
Colómbia wives of exposed flower workers[44]	OR 1.5
Hungary/trichlorfon fish farming cluster[a, 41]	11/15 lb[b]
Spain/father exposed to bipyridyls (paraquat)[45]	OR 2.77
U.S. California/mother lives pesticide use area[c, 42]	OR 2.2
U.S. Minnesota/live in high pesticide use area[43]	OR 1.66
Cleft Lip/Palate	
U.S. California/periconceptual[d] home garden use[40]	OR 3.8
Father pesticide exposed at work	OR 1.7 bs*
U.S. Iowa/live in high agricultural pesticide use area[38]	OR 2.85
Michigan	OR 1.68
Cryptorchidism	
Norway/farmer parents[100]	OR 2.32
Heart Defects	
U.S. Baltimore/home rodenticide 1st trimester[101]	OR 4.7
Home herbicide 1st trimester	OR 2.8
Home insecticide 1st trimester	OR 1.5 bs*
U.S. California/periconceptual[d] home garden use[40]	OR 3.1
Hypospadias/Urogenital	
Norway/farmer parents[100]	OR 2.94
U.S. Minnesota/father pesticide applicator[40]	OR 1.7
Limb Reduction Defects	
Australia/home use more than once 1st trimester[103]	RR 7.0
Norway/farmer parents[100]	OR 2.5
U.S. California/periconceptual[d] home garden use[40]	OR 3.5
U.S. California/mother lives in high crop area[c, 39]	RR 2.4
Mother lives in high pesticide use area	OR 1.9
Neural Tube Defects	
Norway/farmer parents[100]	OR 2.76
Sweden/mother lives on farm[104]	OR 2.2
U.S. California/home use, mother applied[40]	OR 2.9
Home commercial application	OR 2.5
Mother lives within 2.5 miles of agricultural area	OR 1.5
Polythelia (extra nipples)	
U.S./CPP[e] highest level maternal serum DDE[105]	OR 1.9 bs*
Spontaneous Abortion (miscarriage)	
Columbia/wives of floriculture workers[53]	RR 1.79
India/wives of pesticide exposed field workers[54]	OR 3.29
India Bhopal/female survivors[52]	OR 2.49
Pregnant at time of the accident	Increase
Italy/wives of pesticide applicators[55]	OR 7.6
Turkey/40 yrs after HCB[f] exposure episode[51]	Increase
Women with higher HCB[f] levels	OR 2.5
U.S. Minnesota/wives of Cheyenne[g] applicators[56]	RR 2.9
Wives of imidizolinone applicators	RR 2.6
Wives of sulfonylurea applicators	RR 2.1
Wives of fungicide applicators	RR 1.2
Stillbirth (born dead)	
Canada New Brunswick/live in pesticide use area[46]	SRR 2.5
India Bhopal/survivors[52]	OR 2.49
Sudan village pesticide area—mother[47]	AR[h] 16%
U.S./NFMS[i] home exposure—mother[49]	OR 1.5
Home exposure—father	OR 1.3
U.S. California/live in insecticide use area[42]	OR 1.3 bs*
U.S. California/home exposure[50]	RR 1.7 bs*
U.S. Texas/live near pesticide factory (Hispanics)[48]	OR 8.4

Parkinson's Disease Location and Source of Exposure	Ratio
Home Use	
U.S. Washington young onset fumigated house[57]	OR 5.25
Rural Residence	
Australia Nambour[58]	OR 1.8
Canada Saskatchewan/early onset[59]	Increase
China Hong Kong/late onset[60]	Increase
China Taiwan/young onset[61]	Increase
U.S. California/live in high pesticide use county[62]	Increase
U.S./meta-analysis[63]	OR 2.17
U.S./multiethnic community—blacks[64]	Increase
U.S. Kansas/community study[65]	Increase
U.S. Kansas/sibling study[66]	Increase
U.S. Washington State/young onset[57]	OR 2.72
Well Water Use	
China Taiwan/young onset[67]	Increase
India/for more than 10 years[68]	Increase
Italy/farm area[69]	OR 2.0
Italy Emilia-Romagna region[70]	OR 2.8
Spain Madrid/for 30 years or more[71, 102]	Increase
U.S./meta-analysis[63]	OR 1.44 bs*
U.S. Kansas/community study[65]	Increase
U.S. Kansas/sibling study[66]	Increase
U.S./using unfiltered water[64]	Increase

* bs = borderline significance

a. Prevalence returned to normal after insecticide banned
b. lb = live births
c. 1 sq mile/adjacent 8 sq miles, 3rd–8th week of pregnancy
d. 6 months prior to 1 month after estimated conception date
e. Collaborative Perinatal Project, a cohort study of 56,000 pregnancies at 12 medical centers, 1959–1965
f. HCB = Hexachlorobenzene. HCB-treated seed wheat not meant for human consumption used to make bread resulting in large outbreak of acquired porphyria cutanea tarda.
g. Thifensulfuron-methyl, tribenuron-methyl, fenoxaprop-P-ethyl, and MCPA
h. Attributable Risk (% age related to pesticide exposure)
i. National Natality Fetal Mortality Survey, a national probability sample of live births and stillbirths in 1980

Oceano Community Group Tackles Pesticide Drift and Gets Results

San Luis Obispo (SLO) County is known for its rolling hills and rural landscapes. But health risks posed by agricultural pesticide use are increasing, as housing tracts expand into farmland and this agricultural county feels the pressures of development. In 2001 and 2002, a number of pesticide-related illnesses were reported around a strawberry field in Oceano, located in South SLO County. The community organized with the help of Pesticide Watch and the Environmental Center of San Luis Obispo (ECOSLO) to form Neighbors at Risk (NAR). They have been bringing their story to the community, elected officials, and various agencies for a year and are beginning to see results.

In the fall of 2001, a number of Oceano residents complained of trouble breathing, dry cough, severe asthma attacks, and chronic headaches. Their homes encircle a 30-acre strawberry field that had recently been fumigated with a mixture of 57% methyl bromide and 42.6% chloropicrin. Several neighbors made official complaints to the County Agriculture Commissioner's office and contacted ECOSLO, who, with the community, submitted a public comment to the Board of Supervisors and County Health Commission about the illnesses. In response, the latter called for a special meeting in January 2002 in South County to listen to concerns about pesticide use in the area.

ECOSLO and several community members worked together to notify the neighborhood of the meeting by distributing fliers door-to-door. Over 100 community members attended, and many shared stories of illness and concerns related to agricultural pesticide use. The meeting resulted in the Health Commission asking 1) the Health Department to conduct research on illnesses in the area, 2) the Health Commission's Pesticide Use Task Force to investigate the situation, and 3) the County Agricultural Commissioner (CAC) to do public outreach. Research by the County Epidemiologist subsequently found that the community of Arroyo Grande had significantly higher levels of asthma, pneumonia, pleurisy, and male urinary tract cancers. The question remains as to precisely why.

After the January meeting, neighbors in the area formed a coalition called Neighbors at Risk (NAR). Some of NAR's successes include notification by the grower and/or CAC of *all* pesticide applications on the problem strawberry field. NAR, in turn, has organized a notification tree to inform nearby community members of spray days. They have also created a support network for the community to get involved, fill out complaint forms when there are problems, and gain greater understanding of their rights and the regulations governing pesticide use.

Early in 2002, the grower applied a number of insecticides on the strawberry field. The phone tree notification proved effective, and community members felt empowered. A number of adults and children experienced illnesses, which correlated with the spray days. Complaints were filed, and the CAC had to investigate and file a report. NAR pressure and complaints motivated the CAC to take a sample from the windshield of a car after an agricultural pesticide application. Residues from spray drift were detected, but DPR and the CAC claimed that levels of drift on the car were too low to constitute "substantial" drift, so no enforcement action was taken against the grower. The CAC did not sample the air however, so no information exists on the concentration of pesticides in air during the illness episodes.

As a result of the number of complaints, DPR had to sign off on a methyl bromide/chloropicrin fumigation work plan for 2002 that afforded residents more protection. Inspectors had to be on-site to monitor the application. DPR required a 250-foot buffer zone between residents and fumigation, and the percentage of chloropicrin in the fumigant mix was reduced. Again, the phone tree proved effective, empowering the community with knowledge of the application, but again, illnesses were reported.

Symptoms reported by residents during applications of methyl bromide/chloropicrin and other pesticides were correlated with symptoms of exposure to the various chemicals used. Even so, it is difficult to prove exposure to methyl bromide without physician-ordered laboratory tests. The problem with this is that many lack medical insurance or do not visit the doctor for illnesses such as headaches, coughs, or asthma, and physicians may be unaware of pesticide-related illnesses, testing procedures, or reporting requirements.

Herein lies the biggest challenge for communities. Government and the agriculture industry repeatedly argue that applications are done legally and they don't know why people are getting sick. They contend that illnesses cannot be proven to be pesticide-related without confirmation from physician reports or blood tests. Government rarely does air sampling to check for drift and will not cover physician and lab fees. Very few tests can be done to detect pesticides in the body and the cost is prohibitive.

NAR and ECOSLO continue to raise awareness about health risks of pesticide use, people's rights, and alternatives to pesticides. Because of this outreach and education, the strawberry field landowner has agreed to request any grower who leases the land to consider other methods of farming it, and has put out a Request for Proposals so that any farmer, organization, or person can apply to farm the land in a manner sensitive to farmworkers, neighbors, and the land.

Change is possible. The biggest lesson learned is to persist, persist, persist. It was the people of the community of Oceano that created change. Progress in South SLO County demonstrates that a small group of people *can* make a difference!

Sandra Sarrouf, Environmental Center of San Luis Obispo (ECOSLO)

Through the Central Coast Environmental Health Project, ECOSLO and the Environmental Defense Center aim to educate communities at the agricultural-urban interface about health risks associated with pesticide use, how to minimize those risks, the rules and regulations of pesticide use, and what the community's rights are.

Drift affects a diverse population

A recent study published in *Environmental Health Perspectives* evaluated exposures to airborne pesticides in California and estimated that, at a minimum, hundreds of thousands of Californians are exposed to agricultural pesticide drift at concentrations that exceed levels now assumed safe.[106] Although less information is available on the extent and magnitude of urban and indoor exposures, with many more people living in urban areas, it is likely that a substantial number are exposed to pesticide drift with each application in urban settings.

Farmworkers are on the front lines

Farmworkers are most at risk of pesticide drift exposure because of their proximity to and involvement with pesticide applications. While it is illegal to spray a field occupied by workers, no prohibition prevents spraying a field *adjacent* to another with workers present. A poisoning incident in Terra Bella, California, where 24 workers were taken to the hospital with symptoms of acute pesticide poisoning caused by drift from treatment of a neighboring field, illustrates the problems with this regulatory gap.

Sandra Sarrouf

Farmworkers working in fields next to pesticide applications have no legal protection from spray drift.

Between 1991 and 1996 in California, nearly 4,000 cases of agricultural pesticide poisoning were reported, with 44% caused by drift.[7, 8] Between 1998 and 2000, 51% of reported agricultural pesticide poisonings were caused by drift. The actual figure is certainly much higher, since most workers are reluctant to report incidents for fear of retaliation and loss of their jobs.

Between 1998 and 2000, 51% of reported agricultural pesticide poisonings were caused by drift.

Not only acute poisonings affect farmworkers. Chronic, low-level exposure to pesticides is also a very real part of the job, and has been linked to a variety of health problems including increased incidence of some cancers,[107] respiratory problems, neurological deficiencies, asthma, and birth defects.[108]

Farmworkers and their families frequently live on or near farms sprayed with pesticides, resulting in additional exposures. A study of children living in homes within 200 feet of apple orchards showed concentrations of organophosphorus pesticide breakdown products in their urine four times higher than the study group living more than 200 feet away from an orchard.[109] This effect is likely due to pesticide drift that occurs both during and after pesticide applications, as well as to contamination of the home with windblown dust containing pesticide residues. Farm children suffer much higher exposures to pesticides than other populations as a result.[110]

Metam Sodium Poisoning Emergency Forces Earlimart Residents to Flee

On November 13, 1999, a cloud of pesticide vapors from a metam sodium fumigation of a local 160-acre potato field swept over Earlimart, California, engulfing an entire neighborhood in this Central Valley farming town. That afternoon, people both indoors and outside realized something terrible had happened. Yet despite previous incidents of drift, local authorities were not prepared to help residents.

Guadalupe Hernandez and her family were having a barbecue when she saw her one-month-old son's eyes watering. People started coughing, and emergency lights and sirens were activated in the agricultural field one-mile away. The sheriff arrived and told them to leave the area. "Later that same night we began to feel ill with diarrhea, vomiting, and watery eyes," she recounted in a letter. Her three children collectively have chronic bronchitis, damage to their eyesight, liver infection, and asthma since the incident.[111]

That same day, Lucy Huizar's children were outside playing soccer when they complained of a strange smell. She brought them inside and called the fire department. A sheriff told them to remain inside, but later told them to temporarily evacuate or receive medical treatment. Since four in the household had respiratory problems and one child had burning eyes, they sought emergency medical treatment at a nearby school. After an hour, officials told those at the school to strip—in public—because their clothing was contaminated, after which they received only token medical treatment. "The doctor came out and said he had talked to Poison Control and said we were fine to go home." The Huizar's teenage son developed asthma and their daughter continues to have frequent headaches.[112]

While Lucy Huizar was seeking help, Ofelia and Roger Caudillo and their two sons were driving back from Delano. As they drove into Earlimart, they saw emergency vehicles, but no one informed them of the pesticide accident. Though all grew nauseous and had headaches and the youngest son vomited, no one sought hospital care.[113]

In total, 150 were forced out of their homes. Thirty went to the local hospital emergency room, but many more did not go because they could not afford it. Three years later, the battery of chronic health problems continues—long after acute symptoms have disappeared.

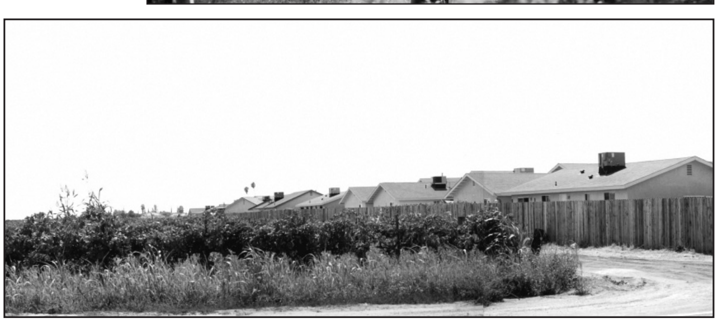
Expanding suburbs and agricultural communities are particularly vulnerable

Residents in suburbs on the agricultural-urban interface and people living or working in agricultural communities incur daily exposure to multiple pesticides. Spray rigs are routinely run up to fence lines and roads, and aerial applicators often inaccurately judge wind speed and amount of offset required to keep spray on the target site. More pervasive, and present even at significant distances from application sites, is post-application drift of volatile pesticides, which results in low-level exposure to multiple pesticides throughout the year.

Residents in suburbs on the agricultural-urban interface and people living or working in agricultural communities are routinely exposed to multiple pesticides.

Every year in September, residents of southern San Joaquin Valley—where nearly a million acres of cotton are grown—suffer from "defoliant flu." Symptoms include headache, respiratory ailments, nausea, and general malaise from chemical defoliants used on cotton—predominantly the neurotoxic organophosphorus compound DEF, the highly acutely toxic compound paraquat, and sodium chlorate, an oxidizing agent and a strong eye, skin, and respiratory irritant. Some become so ill from the chemical cocktail in the air that they evacuate their homes for a month during the defoliation season.[114]

Tracey Brieger



In many locations, houses are very close to cultivated fields. Thus, pesticide air concentrations measured near fields closely model exposures faced by many.

Schoolyard Drift

Agricultural land surrounds Mound Elementary School in Ventura County, with a lemon grove across the street and strawberries grown not far away. Complaints by neighbors about careless pesticide applications went unheeded by the County Agricultural Commissioner, until one day in November 2000 when a cloud of chlorpyrifos (Lorsban), an organophosphorus insecticide, drifted onto the school grounds from the lemon grove. Dozens of students and teachers complained of dizziness, headaches, and nausea following the early morning application. The grower did a second application later that week that also drifted onto the school grounds. Samples from the kindergarten room (45 feet from the grove), desks and play areas (hundreds of yards distant), and other campus locations tested positive for organophosphates.[116] Ironically, the next year U.S. EPA banned all household uses of chlorpyrifos because of long-term risks to children, but left most agricultural uses unchanged.

Children who live or attend school near farmland are particularly vulnerable because their bodies are growing and developing (see page 10). Because their immune systems and organ systems involved in detoxifying chemicals are not as effective as those of adults, exposure to certain pesticides can cause impaired growth and development and lifelong disabilities. Children's exposures to pesticides from all routes are likely to be higher than those of adults, because children eat more food, drink more water, and breathe more air per pound of body weight. Children's behaviors also predispose them to greater exposure. They live close to the ground, which increases contact with and proximity to contaminated dust or grass, and they explore their world by putting objects in their mouths—both of which can contribute to higher pesticide exposures.[115]

Organic and conventional farmers face economic loss

Organic farmers suffer economic damage when contamination from drift lengthens the time required to obtain organic certification, disqualifies produce for the certified organic label (if residues exceed 5% of tolerance),[117] and disrupts beneficial insect populations necessary for a fully integrated organic farming ecosystem.

Organic farmers whose land is contaminated with drift from toxic pesticides are in a particular bind. To become a "certified" organic farm in California requires three years, during which no non-approved pesticides can be applied to the land. Rigorous inspections ensure compliance, and certification can be denied if non-approved pesticides are detected.

When pesticides drift onto already-certified organic farms, farmers risk losing certification and their ability to market their produce as organic, depressing their crop value significantly.

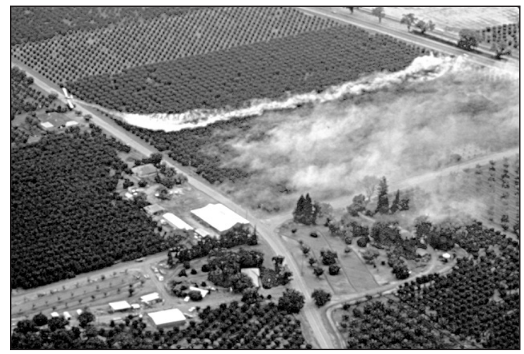
Even conventional farmers occasionally lose part of a crop from pesticide drift. Most of the few existing regulations on pesticide drift in California were implemented because herbicide drift was damaging non-target crops.[118]

Urban communities are also at risk

Pesticide drift is also an urban problem. Urban residents are exposed to drift from pesticide applications in neighboring homes and gardens. Structural fumigations in which a building is covered with plastic tarps and filled with a toxic fumigant like methyl bromide or sulfuryl fluoride, can lead to acute poisonings. When the tarps are removed, or if they leak, high concentrations of these pesticides contaminate air near the site, resulting in symptoms of both acute and sub-acute poisonings. People who live in or near homes or gardens regularly treated with insecticides or herbicides can be exposed through spray drift or post-application volatilization drift (see box below) and through applicator error. Examples abound of illness and injury caused by applications of pesticides in urban settings such as apartments, homes, workplaces, and schools.[7, 119] City residents can also be exposed to low levels of pesticides in air through long-range drift from agricultural areas.[120]

People who live in or near homes or gardens regularly treated with insecticides or herbicides can be exposed through post-application volatilization drift and through applicator error.

Urban apartment dwellers are often at the mercy of landlords, particularly in low-income housing projects. Instead of repairing apartments to exclude cockroaches and ants, landlords often assume it is cheaper to spray. No advance notice or warnings are required in most cases, so residents typically find themselves exposed and unable to do anything about it. In a recent survey of pesticide use during pregnancy among a group



PAN archive

Aerial pesticide applications frequently result in drift of spray droplets onto neighboring streets and property.

Drift Occurs During and After Pesticide Applications

Pesticide drift is comprehensively defined as any airborne movement of pesticides off the target site. Classifying drift as to when and how it occurs makes it possible to predict which pesticides will be most problematic under different conditions. Spray drift occurs during and soon after a pesticide application, while post-application drift occurs after the application is complete.

Spray drift: During pesticide applications, winds or application equipment can blow spray droplets and vapors from mid-air droplet evaporation (with liquid applications) or particles (with dust applications) off site. Fine droplets generated by spray nozzles are the most problematic and can drift long distances before settling. Applicator error or misjudgment can be a significant source of drift. For example, when ground-rig operators fail to turn off spraying or blowing equipment when turning at the end of rows, blower fans or spray pressure may blow pesticides into roadways and neighboring properties. When aerial applicators misjudge the shut-off point when approaching the end of a field, pesticides may drift onto adjacent private property or cars and trucks on roadways instead of the crop. Applicators may also misjudge wind effects. Applications of gaseous fumigant pesticides always involve escape of the gases from the intended application site, generally through the normal (and presently legal) application process, but also through leaking equipment, containers, or tarps. Application-related drift is often visible as a cloud of mist (for liquids) or dust (for solids). Drift of gaseous pesticides like fumigants or volatilized liquids is invisible and often odorless, making it difficult to detect with the senses.

Post-application drift: Pesticide drift does not end when applications are complete. Post-application drift also may occur over many days and even weeks after a pesticide application. Post-application drift takes two forms.

- **Volatilization drift:** Because of their inherent physical properties, some pesticides readily volatilize from the leaf and soil surfaces on which they were initially deposited (see Table 1-4, p. 18). They might be liquids or oils when applied, but evaporate in the heat of the day, drift for a distance, and re-condense when the temperature drops or when they contact a cool surface, just like water vapor condenses on a glass of iced tea on a humid day. This process is repeated many times as the pesticide is carried by prevailing winds. Fumigant pesticides used to treat homes, storage bins, and soil (before planting) are so volatile that they normally exist as gases or very volatile liquids or solids, rendering them extremely drift-prone. Because these pesticides are also applied in large quantities—100 to 400 pounds per acre—they are the most problematic of all pesticides in terms of drift (see Chapter 2).
- **Drift of pesticide-coated dust particles:** High winds in agricultural areas create clouds of dust from pesticide-treated fields. This dust is eventually deposited in yards and parks, as well as in homes and cars, where it can be inhaled or ingested. Children are particularly at risk from this type of exposure because they play on the floor and often put their hands or other objects into their mouths. Both volatile and non-volatile pesticides may cling to dust particles and drift in this manner.

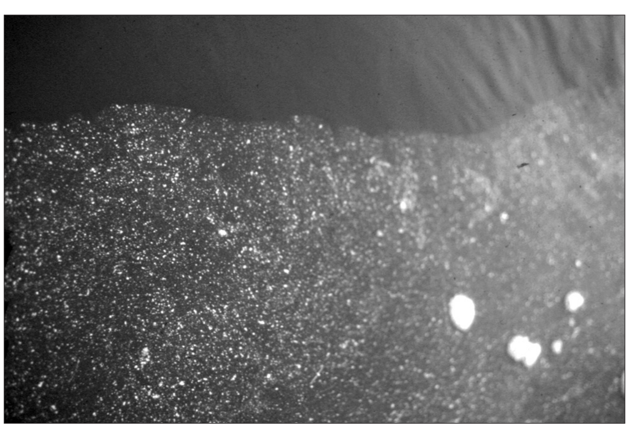
Table 1-4: Top 15 Volatile Pesticides and the Crops They Are Used On

Pesticide	Millions of Pounds Used in California in 2000	CA Bad Actor Pesticide?	Top Crops Treated with This Pesticide
Petroleum oil	19.75	No[a]	Almonds, oranges, lemons, pears, peaches, nectarines, plums, prunes, apples, avocados
Metam-sodium	12.84	Yes	Carrots, tomatoes, potatoes, cotton, bell peppers, onions, leaf lettuce, cantaloupe, head lettuce
Methyl bromide	10.86	Yes	Strawberries, soil pre-plant, outdoor container nursery, outdoor propagation nursery, bell peppers, outdoor flower nursery, sweet potatoes, uncultivated agricultural area, structural pest control, watermelons
1,3-Dichloropropene	4.44	Yes	Carrots, soil pre-plant, sweet potatoes, wine grapes, almonds, potatoes, table and raisin grapes, peaches, tomatoes, melons
Mineral oil	3.90	No[a]	Almonds, lemons, oranges, peaches, prunes, pears, nectarines, apples, plums, apricots
Chloropicrin	3.79	Yes	Strawberries, soil pre-plant, outdoor propagation nursery, head lettuce, bell peppers, outdoor flower nursery, outdoor container nursery, tomatoes, raspberries, uncultivated agricultural area
Petroleum distillates	3.23	No[a]	Public health pest control, oranges, cotton, structural pest control, alfalfa, wine grapes, plums, olives, almonds, table and raisin grapes
Sulfuryl fluoride	2.42	Yes	Structural pest control, landscape, commodity fumigation
Chlorpyrifos	2.09	Yes	Structural pest control, cotton, almonds, alfalfa, oranges, walnuts, sugar beets, lemons, broccoli, table and raisin grapes
Maneb/ETU[b]	1.20	Yes	Walnuts, head lettuce, almonds, leaf lettuce, onions, spinach, tomatoes, potatoes, broccoli, green onions
Trifluralin	1.16	No	Alfalfa, cotton, tomatoes, carrots, safflower, asparagus, sugar beets, soil pre-plant, dried beans, almonds
Diazinon	1.05	Yes	Structural pest control, almonds, head lettuce, leaf lettuce, prunes, peaches, landscape, spinach, sugar beets, tomatoes
Molinate	1.03	Yes	Rice
Thiobencarb	1.01	Yes	Rice
Chlorothalonil	0.68	Yes	Tomatoes, onions, potatoes, celery, landscape, carrots, peaches, nectarines, prunes

a. Petroleum products are used as a mixture of compounds, some, but not all of which are carcinogenic. California's Proposition 65 list of carcinogens includes petroleum products.

b. While maneb itself is not volatile, it breaks down in the environment to form ethylene thiourea (ETU), a moderately volatile carcinogen.

of urban minority women, 35% reported that their homes were treated by an exterminator, frequently more than once per month.[121] When the women wore personal air monitors in their homes, analysis showed that 100% were exposed to the neurotoxic insecticides diazinon, chlorpyrifos, and propoxur. A slightly lower percentage were exposed to at least one of four additional insecticides.



Tim Palmer

Pesticide spray drift residue floats on the surface of the Sacramento River.

Drift impacts wildlife and degrades ecosystems

Drift also affects fish, birds, and other wildlife.[122] The extent of this problem has not been quantified, and it is sometimes difficult to separate the adverse effects caused by drift from those caused by off-site movement of pesticides through surface waters or through direct ingestion of a pesticide or pesticide-contaminated food. However, a number of studies clearly document significant adverse impacts of pesticide drift on non-human life.

Impacts on wildlife in the immediate vicinity of a pesticide application are most severe. Birds and small mammals may be sprayed directly and can be exposed to a lethal dose through inhalation or body contact. If they survive the initial spraying, they may ingest more pesticide through grooming or preening as they try to clean their fur or feathers. Fish and other aquatic organisms can die when a watercourse is sprayed or when pesticide-contaminated rainwater brings drifting pesticides back to earth. Diazinon—an insecticide used to spray dormant orchards in the rainy season—contaminates rainwater to such a degree that it has been found to be toxic enough to kill *Daphnia,* a small invertebrate representative of the types of invertebrates used as a food source by fish.[123]

Pesticide drift has ecological impacts far from application sites as well. A number of studies demonstrate that winds transport pesticides applied in California's Central Valley to the Sierra Nevada mountains.[124] A recent U.S. Geological Survey revealed the presence of organophosphorus pesticides in the tissues of frogs in the Sierra Nevada mountains 50 miles from agricultural areas.[125] Work on the distribution and abundance of the California red-legged frog finds significant population declines in mountain areas downwind of substantial pesticide use.[126] Recognizing the hazards drifting pesticides pose to ecosystems, the Ninth Circuit Court recently decided that aerial pesticide applications over waterways must have a permit to "discharge" the toxic substance to waterways.[127]

A recent U.S. Geological Survey revealed the presence of organophosphorus pesticides in the tissues of frogs in the Sierra Nevada mountains 50 miles from agricultural areas.

Pesticide Drift Significantly Contributes to Central Valley Air Woes

The spotlight was on California's Central Valley in the summer of 2002 when news broke that this agricultural area nearly beat Los Angeles for the dubious honor of having the state's worst air quality. Kern and Fresno counties were second only to Riverside County for the most unhealthy air.[128] The health outcomes are tangible, with Fresno asthma rates highest in the state and second only to New York and Chicago nationwide.[129] The state tracks emissions of Reactive Organic Gases (ROGs) that react with air and sunlight to form ground-level ozone, an air pollutant known to cause and exacerbate asthma and other respiratory diseases. In the San Joaquin Valley in 2001, internal combustion engines accounted for 40% of the total ROGs, general farming operations 15%, and pesticide use 8.2%.[130] The table below highlights the top contributing pesticides for ozone-forming emissions in different regions of the state. A tally of only ozone-forming compounds is just part of the pesticide air pollution picture. Pesticides typically have other toxicity as well and may cause cancer, birth defects, sterility or nervous system disorders. Additionally, some pesticides do not form ozone (e.g., sulfur, sodium chlorate and sulfuryl fluoride), yet they still cause respiratory irritation and/or asthma and are used in large quantities in the state.

Relative Contributions of Different Products to Pesticide Emissions of Reactive Organic Gases in 2000*

Pesticide[a]	San Joaquin Valley	Sacramento Valley	Southeast Desert	Ventura	South Coast
Metam sodium products	21.9%	19.4%	44.3%	82.2%	43.8%
Methyl bromide products	16.9%	6.6%	34.3%	5.2%	2.3%
1,3-Dichloropropene products	16.9%	2.9%	7.5%	1.5%	< 1.4%
Chlorpyrifos products	7.0%	4.8%	1.6%	2.4%	11.8%
Trifluralin products	3.0%	3.7%	1.4%	< 0.3%	< 1.4%
Diazinon products	< 1.3%	< 2%	0.9%	< 0.3%	8.5%
Molinate products	0%	18.3%	0%	0%	0%

* Source: Reference 130b.

a. Products with multiple active ingredients are listed under the primary active ingredient. The emissions measurements include volatile "inerts" such as solvents.

How much is too much? Determining "acceptable" concentrations

To assess the potential impacts of drift on human health requires two types of information: 1) air monitoring data that show how much pesticide is in the air during and after applications, and 2) accurate, up-to-date information on pesticide concentrations in air that are likely to harm people. Beginning in 1998[131] and continuing into 2002, such information was finally available for eight high-use pesticides (more than 750,000 pounds used in 2000) (see Table 1-5, next page). Three additional pesticides—chloropicrin, sulfuryl fluoride, and methyl iodide—are included in this discussion because of their high use and/or potential for drift, even though complete data are not yet available for these chemicals.

Prevention of pesticide-induced health problems requires some knowledge of health impacts associated with different levels of exposure. This information is usually obtained from studies on laboratory animals and occasionally from accidental human exposure to the chemical. The process of determining "acceptable" levels is called risk assessment (see Appendix 2). U.S. EPA and DPR have recently finalized

Table 1-5: Pesticides of Concern Evaluated in This Report

Pesticide	Reported Pesticide Use in California in 2000 *(millions of lbs active ingredient)*[a]	Pesticide Volatility[b]	Status of Air Monitoring	Post-1996 Risk Assessment Available?
Metam sodium/MITC	12.84	Very high (MITC)	Completed	Yes–2002, DPR[132]
Methyl bromide	10.86	Very high	Completed	Yes–2001, DPR[133]
1,3-Dichloropropene (Telone)	4.44	Very high	Completed	Yes–1997, DPR,[134] 2000, U.S. EPA,[135] 1998, U.S. EPA[136]
Chlorpyrifos	2.09	Moderate	Completed	Yes–2001, U.S. EPA[137]
Propargite	1.33	Low	Completed	Yes–2001, U.S. EPA[138]
Diazinon	1.05	Moderate	Completed	Yes–2002, U.S. EPA[139]
Molinate	1.03	High	Completed	Yes–2002, U.S. EPA[140]
Paraquat	0.98	Low	Ambient only[d]	Yes–1997, U.S. EPA[141]
Chloropicrin	3.79	Very high	Completed, but not published	No
Sulfuryl fluoride	2.42	Very high	Slated for 2003	No
Methyl iodide[c]	0	Very high	None planned	No

a. Pesticide use data from 2000 DPR Pesticide Use Reports, reference 2b.

b. Volatility rankings are based on the vapor pressure (Vp) of the chemical at 20-25°C, an inherent physical property of the chemical that is a good predictor of whether a pesticide will drift off-site by volatilization after application. We rank volatility using the following scheme: Very high: Vp $\geq 10^{-2}$; High: Vp between10^{-2} and 10^{-4}; Moderate: Vp between 10^{-4} and 10^{-6}; Low: Vp $\leq 10^{-6}$; Very low: Not measurable.

c. Methyl iodide is a proposed replacement for methyl bromide, but not yet registered for use in California.

d. No near-field monitoring was conducted for paraquat, only ambient air monitoring (see pp. 39-40).

(or nearly finalized) new risk assessments for a number of commonly used pesticides. Because of recent changes in pesticide registration laws requiring risk assessors to take into account the most vulnerable members of the population (children and pregnant mothers), these new risk assessments are more protective than older ones, although many gaps remain (see page 21).

Risk assessment for non-cancer health effects from inhalation exposure provides a concentration of the chemical in air that is not likely to cause adverse health effects—the "acceptable" concentration. Different agencies use different terms for this concentration. Throughout this report, we refer to this number as the Reference Exposure Level (REL). RELs are calculated for acute exposure (1 to 24 hours), sub-chronic exposure (several weeks to several years), and chronic exposure (several years to a lifetime) and depend on body weight and breathing rate. RELs are lower for children than adults because children have a faster breathing rate and thus take in more air (and more air contaminants) per pound of body weight. We used standard methodology based on body weight and breathing rate to determine the REL for a one-year-old from the adult RELs developed by the agencies. The higher dose children receive is one reason they are affected by airborne toxicants to a greater degree. Children are also more vulnerable to chemical insults because their organ systems, immune system, and nervous system are developing, and their detoxification systems are not capable of metabolizing toxicants as an adult's can. Table 1-6 summarizes acute and sub-chronic non-cancer RELs for adults and children for the pesticides discussed in this report, and Appendix 2 describes the methods used to obtain these numbers.

Children are more vulnerable to chemical insults because their organ systems, immune system, and nervous system are developing.

For carcinogenicity, risk assessment provides an estimate of the cancer potency of the chemical. From this, U.S. EPA or DPR calculates the amount of daily exposure over a lifetime that would result in a probability of one additional case of cancer in a million people, a risk these agencies generally consider to be acceptable. The only carcinogenic pesticide we evaluated in detail was 1,3-dichloropropene (Telone), with a one in one million risk level of 70 nanograms per cubic meter (ng/m^3) for a 70-year lifetime (see Appendix 2 for details). Because cancer risk is treated as additive over a lifetime, a single high exposure event can have the same effect as a lifetime of low exposures.[142]

Table 1-6: Non-Cancer Reference Exposure Levels and Target Toxicity of Pesticides Evaluated*

Pesticide	Adult Acute REL[a] (ng/m³)	Child Acute REL[b] (ng/m³)	Toxic Endpoint	Adult Sub-chronic REL[a] (ng/m³)	Child Sub-chronic REL[b] (ng/m³)	Toxic Endpoint	Data Source
Chlorpyrifos	3,880	170	Neurotoxicity: cholinesterase inhibition	3,880	170	Neurotoxicity: cholinesterase inhibition	U.S. EPA RED, ref. 137
Diazinon	330	145	Neurotoxicity: cholinesterase inhibition	330	145	Neurotoxicity: cholinesterase inhibition	U.S. EPA RED, ref. 139
1,3-Dichloropropene (Telone)	404,000 (90 ppb)	176,000 (39 ppb)	Body weight reduction	276,000 (61 ppb)	120,000 (27 ppb)	Degeneration and necrosis in the nasal epithelium	DPR risk assessment, ref. 134
Methyl bromide[c]	815,000 (210 ppb)	354,000 (91 ppb)	Developmental toxicity	7,800 (2 ppb)	3,400 (1 ppb)	Neurotoxicity	DPR risk assessment, ref. 133
MITC	66,000 (22 ppb)	66,000 (22 ppb)	Eye irritation	3,000 (1 ppb)	1,300 (0.44 ppb)	Increased atrophy of the nasal epithelium	DPR risk assessment, ref. 132
Molinate	23,300	1,010	Developmental neurotoxicity	3,000	130	Decreased number of implants and increased percentage of abnormal sperm. Testicular degeneration.	U.S. EPA Preliminary risk assessment, ref. 140

*See Appendix 2 for detailed discussion, sample calculations, and specific parameters for each pesticide.

a. For a 70 kg adult.

b. For a one-year-old child.

c. DPR recently proposed to raise the REL for methyl bromide, based on results of a controversial toxicology study. See page 50.

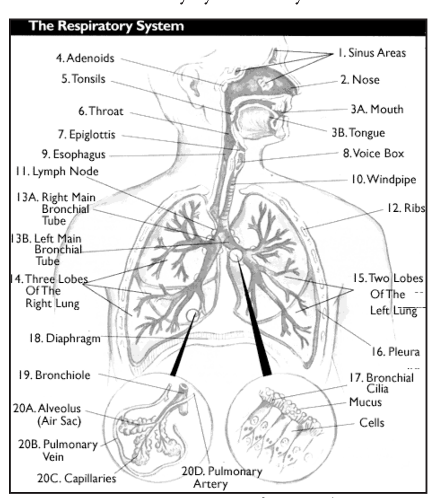
Why risk assessment doesn't tell the whole story

In theory, risk assessment provides an estimate of how much of a particular toxin the average person can be exposed to without experiencing adverse effects. In fact, the process is deeply flawed because it does not consider the real-world mix of chemicals most people encounter—the wide variety of pesticides in food and water, on lawns, and in homes and workplaces; fumes from gasoline and vehicle exhaust; and other toxic substances in food, air, and water. The impacts of this chemical cocktail are unknown, but additive or synergistic effects are likely.

Risk assessments may be under-protective of human health for many other reasons. These include toxicity data gaps for many types of adverse effects, use of uncertainty factors that do not reflect real differences in susceptibility to toxic effects between laboratory animals and humans or between different individuals, and undue influence of pesticide manufacturers and pesticide users on agencies conducting the risk assessments.[143] The use of such a flawed and unscientific process for determining "acceptable" exposure to a single pesticide, or even a class of pesticides with similar mechanisms of action,[144] is far from reassuring.

Human Lungs Are Efficient Pesticide Traps

Air monitoring stations that collect air samples act in essentially the same way a person or animal would—they are "breathing" air near the field. Similar to how a filter traps pesticides during air sampling, the lungs trap pesticides as well. The extensive branching and high surface area of the lungs serves the primary job of oxygenating the blood, but also allows air pollutants to be absorbed directly into the bloodstream and circulated to all parts of the body. Inhalation is such an efficient method of introducing organic compounds into the bloodstream that many drug and anesthesia delivery systems rely on it.



 For more information on how you can support to fight lung disease, the third leading cause of death in the U.S., please contact The American Lung Association at 1-800-LUNG-USA (1-800-586-4872) or visit the website at www.lungusa.org.

2 Pesticide Concentrations in Air Frequently Exceed Levels of Concern

Our analysis compared measured air concentrations of eight high-use, drift-prone pesticides used in agricultural settings to the Reference Exposure Levels (RELs) for each pesticide. Results indicate that for most of the pesticides evaluated, measured concentrations exceeded levels of concern for both adults and children, often by large margins. We determined the factor by which measured concentrations in air exceeded the REL—the Hazard Quotient (HQ)—for both an adult male and a one-year-old child for each pesticide, and for both acute (short-term) near-field exposures and sub-chronic (seasonal) exposures measured in regions of high pesticide use, but some distance from application sites. This chapter presents detailed analysis for each pesticide (see Table 2-1).

For most of the pesticides evaluated, measured concentrations exceeded levels of concern for both adults and children, often by large margins.

HQs greater than one represent a health concern —the larger the number, the higher the probability of adverse effects from pesticide exposure. For near-field (30–500 feet) exposures, pesticide concentrations exceeded levels of concern for MITC, chlorpyrifos, and diazinon (adults and children), and for molinate (children only). Seasonal, ambient exposures exceeded levels of concern for methyl bromide and MITC (adults and children), and chlorpyrifos, diazinon, and for molinate (children only). Chronic exposures to 1,3-dichloropropene (Telone) projected from current use levels exceed the "acceptable" cancer risk of one in one million. Because of the extremely low volatility of propargite, measurable air concentrations were detected only during application near the field. The behavior of paraquat is expected to be similar because of its similarly low volatility. Exposures to these pesticides are more likely to occur through contact with surfaces contaminated with residues from spray drift or pesticide-contaminated soil particles, rather than through inhalation of the volatilized pesticide.

HQs presented here should be viewed as exposure estimates that may or may not represent worst-case exposure scenarios, and that may not necessarily represent the precise exposure individuals experience.[145] For most pesticides, few monitoring studies are available, and these studies only provide results for applications conducted according to label instructions and for exposure estimates to a single pesticide. Where more than one monitoring study was available (methyl bromide, metam sodium, and 1,3-dichloropropene), we provide detailed results from those studies that are most representative of applications made under current conditions of use for that pesticide, and present the range of results from all available studies meeting these criteria. All pesticide applications discussed in this chapter were conducted under legal conditions and according to label instructions. Therefore, the monitoring results represent a best-case scenario in terms of applicator compliance.

Table 2-1: Hazard Quotients for Non-Cancer Effects of Eight Drift-Prone Pesticides*

Pesticide	Hazard Quotient[a] for an Adult Male	Hazard Quotient[a] for Children Less Than One Year Old
Methyl bromide	Acute: **NA**[c] Sub-chronic: **0.6–3.8**	Acute: **NA**[c] Sub-chronic: **1.2–7.7**
MITC/Metam sodium	Acute: **3.7–111** Sub-chronic: **0.1–1.4**	Acute: **3.7–111** Sub-chronic: **0.3–3.2**
1,3-Dichloropropene[b]	Acute: **0.15** Sub-chronic: **0.00014–0.029**	Acute: **0.35** Sub-chronic: **0.00033–0.068**
Chlorpyrifos	Acute: **8** Sub-chronic: **0.007–0.02**	Acute: **184** Sub-chronic: **0.2–4.8**
Diazinon	Acute: **16** Sub-chronic: **0.03–0.15**	Acute: **39** Sub-chronic: **0.07–0.34**
Molinate	Acute: **0.97** Sub-chronic: **0.12–0.24**	Acute: **22** Sub-chronic: **2.8–5.6**

* See Appendix 2 for methods of calculation of HQs and other important notes for each pesticide.

a. Hazard Quotient = measured concentration divided by the REL.

b. Concentrations of 1,3-dichloropropene did not exceed acute or sub-chronic RELs. However, chronic exposures to 1,3-dichloropropene (Telone) projected from current use levels exceeded the "acceptable" cancer risk of one in one million by as much as a factor of 56 in 2000 and 28 in 2001.

c. NA = not available. See page 25.

Near-field monitoring studies represent the highest anticipated exposures and are most representative for people living within 500 feet of an application site.[146] Such proximity is increasingly common as suburbs expand into agricultural areas. These near-field studies are somewhat better defined than seasonal ambient air monitoring studies because the conditions of application are more precisely known. In addition, because the air concentration of a pesticide is directly related to its volatilization potential, evaluation of near-field concentrations of pesticides with similar volatilization potentials provides an expanded data set for comparison that permits a more informed assessment of how representative results are. In contrast, results of ambient monitoring may not be representative (particularly if only a single study was done over a relatively short time). Although ambient monitoring takes place during the season of highest *historic* use for each particular pesticide, sampling periods did not always coincide with *actual* pesticide use in the areas near monitoring stations.

Notwithstanding that available monitoring data are not comprehensive, the available data indicate that many Californians are routinely exposed to levels of airborne pesticides that exceed both acute and sub-chronic levels of concern.

How much pesticide are you breathing? Air monitoring provides some answers

The state of California now has a sizeable collection of pesticide air monitoring data, collected as part of its work under the Toxic Air Contaminant (TAC) program (see Chapter 3) and efforts to regulate fumigant pesticides. This work is the most comprehensive pesticide air monitoring effort in the U.S., with data now available for approximately 40 pesticides.[147] The Air Resources Board (ARB) and the California Department of Pesticide Regulation (DPR) have conducted most of the sampling. Other organizations besides the state of California have done more limited monitoring, including the U.S. Geological Survey (USGS)[120a, 148] and the Environmental Working Group (EWG).[149]

Two types of studies are typically done for each pesticide, application site monitoring and seasonal monitoring of ambient air.

- **Application site monitoring** involves sampling air near a pesticide-treated field during and after an application to determine how the air concentration of the pesticide changes as a function of time after application. Air samplers are typically placed 30–500 feet from the field boundary on each side of the field. This type of study focuses

Important Terms

Reference Exposure Level (REL): Also referred to as Reference Concentration (RfC). The concentration of a chemical in air that the agency conducting the risk assessment considers "acceptable" for a given exposure scenario (acute, sub-chronic, or chronic) in nanograms per cubic meter (ng/m^3). A nanogram is one billionth of a gram and a cubic meter of air is about the size of a large television. The REL is generally deemed the level below which no adverse health effects are anticipated, although this assumes exposure to only a single chemical for most chemicals. In this report, we provide RELs for a 70 kg (154 pound) adult male and a 7.6 kg (17 pound) child (average weight of a one-year-old). See Appendix 2 for details on calculation of RELs.

Acute REL: The "acceptable" concentration of a pesticide in air for a short time period, typically one to 24 hours.

Sub-chronic REL: The "acceptable" concentration of a pesticide in air for an intermediate time period, typically one month to several years.

Chronic REL: The "acceptable" concentration of a pesticide in air over a long time period, typically several years to a lifetime.

Lifetime Cancer Risk: The probability (for example, one in one million or one in one hundred thousand) that an individual would develop cancer from breathing air contaminated at a particular concentration averaged over a 70-year lifetime. In a large population, a one in one million cancer risk means there would be one additional case of cancer over the background incidence rate per million people from exposure at this level. Many public health experts become concerned when cancer risks exceed one in one million, and most do so when risks exceed 10 in one million.

Hazard Quotient (HQ): The ratio of an observed concentration of a chemical in air to the REL. If the HQ is greater than one, the measured air concentration is higher than the DPR or U.S. EPA "acceptable" level.

Interpreting Plots of the Data

Near-field Exposures (Figures 2-2, 2-4, 2-6, 2-8, 2-10 and 2-12): These figures show how the observed concentration of a pesticide in the air adjacent to an application site changes over time during and after application. In ARB studies, the distance from the monitoring station to the edge of the treated area was typically 30–500 feet. The application period is shaded on the graph. Horizontal lines mark the acute or short-term RELs for adults and children and allow comparison of the observed air concentration to an "acceptable" level throughout the course of monitoring—usually 3–4 days, but as long as 10.

Seasonal Ambient Exposures (Figures 2-3, 2-5, 2-7, 2-9, and 2-11): These figures show the observed average seasonal concentrations of a pesticide in ambient air in regions of high use but not directly adjacent to an application site. Presented on the same graph for comparison are sub-chronic or intermediate term RELs for adults and children.

on a single pesticide. As might be expected, the highest concentrations of airborne pesticides are found closest to application sites.

- **Seasonal ambient air monitoring** entails sampling air in regions of high pesticide use during a period of maximum use in that region. Samplers are placed on fire stations and schools in towns that are close to pesticide applications, but not immediately adjacent to fields (from several hundred yards to several miles away). This type of study may focus on a single pesticide, or survey many at once. Monitoring is done 4–5 days per week for up to several months during the season of peak use for the pesticide(s) of interest. Concentrations measured at these locations are typically lower than those next to application sites.

ARB and DPR data provide valuable information on air concentrations of pesticides during and after applications and are the basis of this report.

Fumigant pesticides pose serious risk of harm from drift

Drift from fumigants is both dangerous and inevitable

Fumigants are pesticides applied to soil, stored products, and building structures as biocides, designed to kill all manner of pests such as insects, nematodes, fungi, and weeds. Soil fumigants are typically injected into the soil or applied with irrigation water in a "chemigation" process. To be effective, fumigants must be highly toxic to target pests and are either applied as gases or break down into highly volatile compounds upon contact with water, air, or heat. These pesticides and their breakdown products are highly prone to drift and both travel with the wind and remain suspended in the air when air is very still or when atmospheric inversions develop. Fumigants are also applied at very high rates—100–400 pounds per acre—much higher than the more typical application rates for many pesticides of 1–5 pounds per acre. These characteristics of fumigants and their use patterns contribute to the extreme drift hazard they pose.

The most widely used fumigant pesticides in California agriculture are metam sodium, methyl bromide, 1,3-dichloropropene (Telone), and chloropicrin (see Figure 2-1). In urban structural fumigations for termite infestations, sulfuryl fluoride and, less frequently, methyl bromide are used. These pesticides are all either highly acutely toxic (U.S. EPA Category I), neurotoxicants, reproductive or developmental toxicants, and/or probable carcinogens (see Table 2-2). Over the past decade, California use of the soil fumigants 1,3-dichloropropene, metam sodium, and chloropicrin has risen, driven largely by increased pre-plant soil fumigation for crops like cotton, tomatoes, melons, and garlic and continued high use on strawberries. Methyl bromide use has begun to decrease due to the impending phaseout under the Montreal Protocol because of its ozone-depleting ability. There are a number of biological alternatives to fumigants to control soil-borne pests. Ironically, soil fumigants kill all soil organisms, including the beneficial ones, perpetuating further chemical dependence.

The following sections describe air monitoring results and immediate and chronic health concerns for each major soil fumigant.

Use of Soil Fumigants in California, 1988–2000

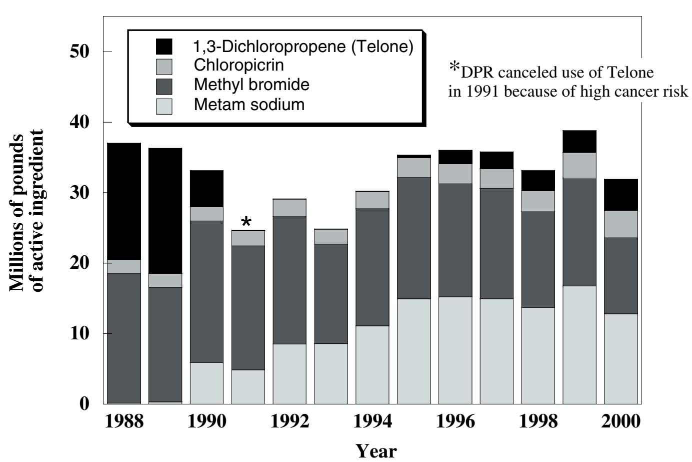


Figure 2-1
The mix of fumigant pesticides used in California agriculture has changed over the last decade. Note: Data from before 1990 do not include all metam sodium use because it was not then a restricted use pesticide.
Source: California Pesticide Use Reporting Data, California Department of Pesticide Regulation. Error analysis and data cleanup for 1988–1989 data by Professor Carlos Davidson.

Methyl bromide: Seasonal levels exceed reference exposure levels in high-use areas

Methyl bromide is a highly toxic pesticide used to fumigate soil before planting many crops, including strawberries, tomatoes, nursery plants, and grapes. It is also used to fumigate stored nuts and grains, other commodities, and potting soil, as well as in structural pest control, with 10.8 million pounds used in California in 2000 (see map on page 26). Use is heaviest in Monterey, Ventura, Santa Barbara, Fresno, and Kern counties.[2b]

Methyl bromide is neurotoxic and severely irritating to the skin and lower respiratory tract. It is also a

Table 2-2. Soil Fumigants: Toxicity, Top Crops, and Top Counties

Fumigant Pesticide	Toxicity	Top Crops in 2000	Top Counties for Use of This Chemical in 2000
Methyl bromide	Highly acutely toxic[a] Developmental toxicant[b] Neurotoxicant[c]	Strawberries, nursery plants, soil pre-plant	Monterey, Ventura, Santa Barbara, Fresno, Kern
Metam sodium[e] **Methyl isothiocyanate (MITC)**[f] **Methyl isocyanate (MIC)**[f] **Hydrogen sulfide (H_2S)**[f]	MITC/MIC/H_2S are highly acutely toxic[a] Metam sodium is a developmental toxicant[b] and probable carcinogen[d]	Carrots, tomatoes, potatoes	Kern, Fresno, Imperial, Los Angeles, Santa Barbara
Chloropicrin	Highly acutely toxic[a] Chronic respiratory damage[150]	Strawberries, tomatoes, nursery plants	Monterey, Ventura, Santa Cruz, Santa Barbara, Orange
1,3-Dichloropropene (Telone)	Highly acutely toxic[a] Probable carcinogen[d]	Carrots, soil pre-plant, sweet potatoes	Merced, Kern, Fresno, Stanislaus, Monterey

a. Highly acutely toxic chemicals cause immediate illness at low exposure levels. U.S. EPA classifies these chemicals as Category I toxicants.

b. Included in the California Proposition 65 list of known carcinogens or reproductive toxicants. See reference 151.

c. Included in the U.S. EPA Toxics Release Inventory (TRI) list of neurotoxicants. See reference 152.

d. Ranked by U.S. EPA as a B2 (Probable) carcinogen. See references 135 and 136.

e. Metam potassium and dazomet are less widely used soil fumigants that also break down to form MITC.

f. MITC, MIC, and H_2S are volatile breakdown products of metam sodium, metam potassium, and dazomet.

developmental toxicant, causing birth defects. This chemical is an insidious poison because it is virtually odorless, and symptoms of acute poisoning of the lungs and nervous system may be delayed for many hours.[153] Because it has little odor, it is normally combined with chloropicrin—a fumigant with an acrid odor—to improve application safety. Yet chloropicrin poses its own health concerns, including severe irritation of the eyes and respiratory system at low concentrations (see below).

Methyl bromide is an ozone-depleting chemical, and most uses are to be phased out in developed countries in 2005 and in developing countries in 2015 under the Montreal Protocol. Appendix 4 summarizes the history of methyl bromide regulation in California and Chapter 3 offers a more extensive discussion of its California regulatory history on page 49.

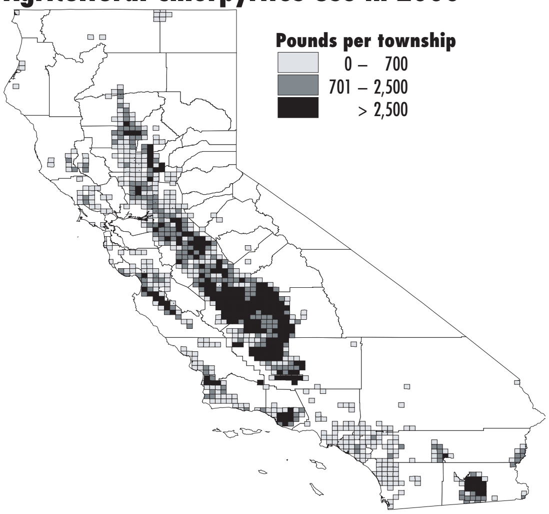
Along California's Central and South-Central Coast from Santa Cruz to Ventura, strawberries—often planted close to subdivisions, labor camps, and schools—are the leading crop for methyl bromide use. Methyl bromide drift has sparked many farmer-neighbor conflicts (see page 14). An EWG study published in 2000 found 87 public schools were located within a mile and a half of fields treated with at least 10,000 pounds of methyl bromide in 1998.[149a] Ventura County is a methyl bromide hotspot, with 1.73 million pounds of methyl bromide (16% of the state total) applied in 2000.[2b]

In a risk assessment finalized in February of 2002, DPR determined the acute REL for methyl bromide to be 815,000 ng/m^3 (210 parts per billion, ppb) for adults.[154] We calculated an acute REL of 354,000 ng/m^3 (91 ppb) for a one-year-old child (see Appendix 2 for details on calculation of RELs). DPR determined the adult sub-chronic REL for seasonal (8 weeks) exposure to be 7,860 ng/m^3 (2 ppb), and the sub-chronic REL for a one-year old child to be 3,370 ng/m^3 (1 ppb). These RELs do not include an additional uncertainty factor to take into account the particular vulnerability of children to toxic substances.

DPR and industry have monitored 39 methyl bromide applications to evaluate acute, near-field exposures.[133] Of the 39, seven resulted in exposures exceeding the adult acute REL at the edge of the buffer zones, which ranged from 30–300 feet in these studies.[155] None of the available application site monitoring studies are truly representative of current application conditions. Buffer zones have been changed since these studies were conducted, and none of the studies used the currently accepted canister sampling technique. The charcoal tube sampling technique that was used is not as effective at trapping methyl bromide and results in substantial under-reporting of concentrations.[156]

In 2000, ARB conducted seasonal, ambient air monitoring for methyl bromide during the peak fumigation season in two regions with high methyl

Agricultural Chlorpyrifos Use in 2000



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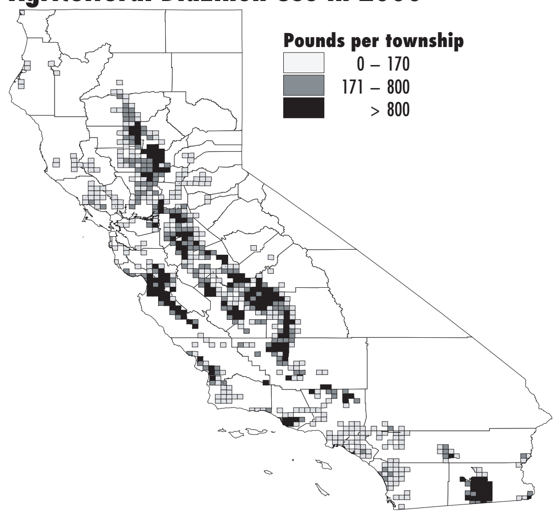
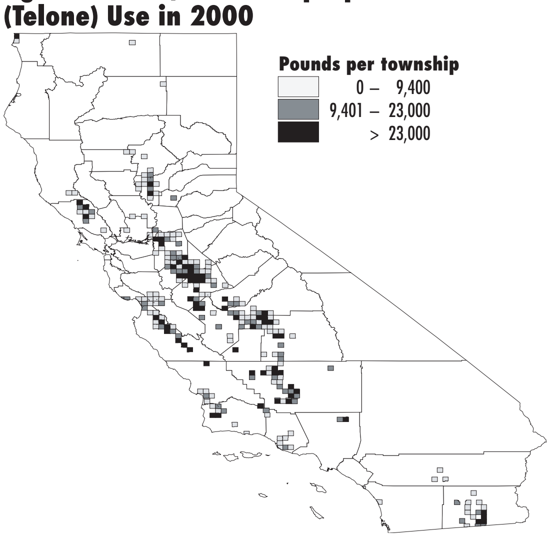
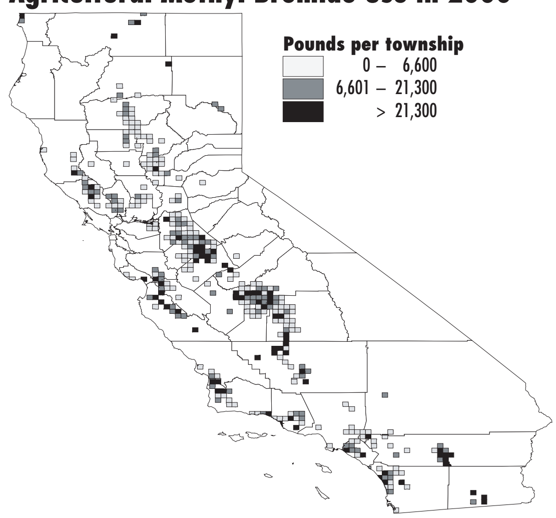


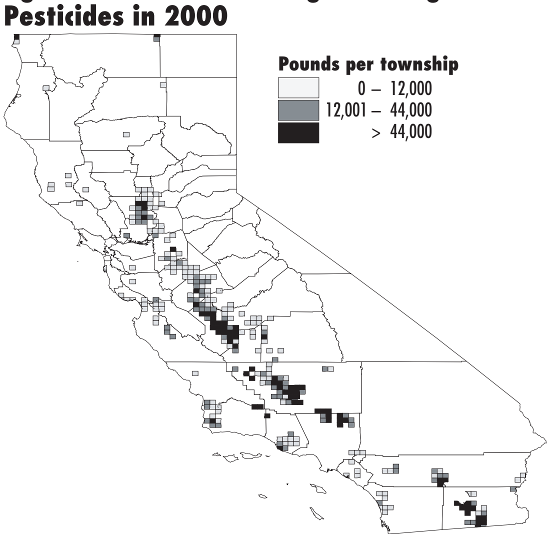
Agricultural 1,3-Dichloropropene (Telone) Use in 2000



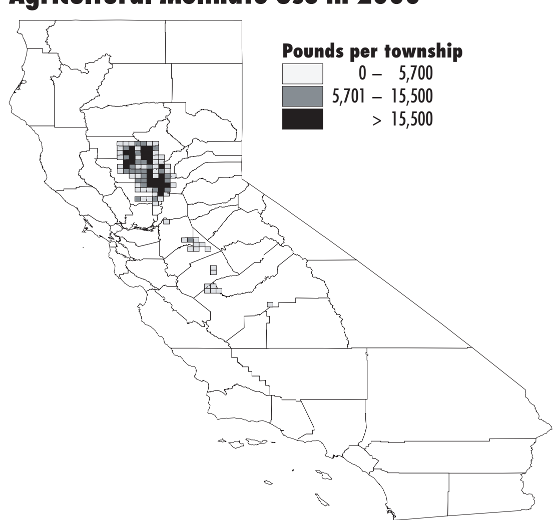
Agricultural Methyl Bromide Use in 2000



Agricultural Use of MITC-generating Pesticides in 2000



Agricultural Molinate Use in 2000



Agricultural Use of Six Drift-Prone Pesticides in California

Breaks in the shading, shown in the legend of each map, are based on a percentile ranking of pounds of pesticide active ingredient used per township (a 6x6 square mile area). The lightest shading represents pesticide use in pounds per township equal to the 50th percentile, meaning that 50% of the pesticide use is below the higher value of the specified range. The medium gray shading represents the range of pounds used per township between the 50th and 75th percentile. The black squares represent all pesticide use above the 75th percentile, or the top 25% of pesticide use for the particular pesticide.

bromide use, the Central Coast and Kern County (Table 2-3). However, because the study was designed to evaluate use of 1,3-dichloropropene and metam sodium, as well as methyl bromide, not all monitoring stations were located in areas of highest methyl bromide use. Monterey and Santa Cruz sites were chosen for proximity to areas of high methyl bromide use, but Kern County sites were selected primarily for proximity to areas of high Telone use, not necessarily near areas of peak methyl bromide use.

In 2000, air concentrations of methyl bromide exceeded the sub-chronic REL for children and adults at four Central Coast sites near Salinas and Watsonville and one Kern County site during peak fumigation season. In 2001, monitoring revealed levels exceeding the sub-chronic REL once again at the sites sampled in 2000, as well as at a new Salinas site and a Santa Maria site where industry conducted monitoring as a condition of registration.[157, 158] Except for one site (MacQuiddy School) in 2001, no methyl bromide was applied within one-half mile of any of the air monitoring stations, yet concentrations exceeded both adult and child sub-chronic RELs.[159]

PAN archive

Fields fumigated with methyl bromide are covered with plastic tarps to slow the escape of the gas from the soil.

Levels were higher in the previous year when methyl bromide was used within several hundred yards of these monitoring stations.[160]

Using the 2000 and 2001 monitoring data, DPR correlated air levels of methyl bromide with pounds used in the nearby area, verifying that higher use results in higher methyl bromide ambient air concentrations. DPR scientists used this correlation to calculate that applications would need to be limited

Table 2-3: Seasonal Methyl Bromide Concentrations in Ambient Air

County	Site	Average Conc. in 2000[a, b] (ppb)	Average Conc. in 2001[a, b] (ppb)	Weekly Methyl Bromide Use within 0.5 Mile during 2001 Air Monitoring[d] (pounds per week)
Monterey	La Joya Elementary, Salinas	**3.79**	**2.82**	0
	Pajaro Middle School, Watsonville	**7.68**	**2.99**	0
	MacQuiddy School, Salinas	not tested	**5.51**	3,034
	Salinas "background site"	**1.29**	**1.38**	0
	Chular Elementary	0.64	0.56	0
Santa Cruz	Salsepuedes Elementary, Watsonville	**2.6**	**1.22**	0
Santa Barbara	Edwards Community Ctr., Santa Maria [c]	not tested	1.3	0
Kern	Cotton Research Station, Shafter	**2.2**	**2.8**	3,828
	Air Monitoring Station, Bakersfield	0.19	0.12	0
	Vineland School, Bakersfield	0.099	0.078	0
	Arvin High School, Arvin	not tested	0.08	0
	Mountain View School, Lamont	0.092	0.081	0
	Mettler Fire Station, Mettler	0.084	0.065	0

Source: References 173a–d.

a. Sub-chronic RELs: Child, 1 ppb; Adult, 2 ppb. Concentrations above the sub-chronic REL for children are bold.

b. Average air levels over 7 to 9-week monitoring periods. Monterey/Santa Cruz counties—September 11 to November 2, 2000 (7 weeks), and September 8 to November 7, 2001 (8 weeks); Kern County—July 19 to August 31, 2000 (7 weeks), and June 30 to August 30, 2001 (9 weeks).

c. Source: Reference 173e.

d. Source: Reference 159.

to no more than 20,000 pounds in any given township (36-square-mile area) in a single month to control air levels to the sub-chronic REL of 1 ppb.[161]

Late in 2001, ARB added methyl bromide and 1,3 dichloropropene (Telone) to routine air toxics monitoring conducted at a network of 20 stations in urban areas of California. Methyl bromide was detected during the fall 2001 fumigation season in San Jose, San Francisco, and Modesto. Since little methyl bromide is used in these areas in the fall, the most plausible source is long-distance drift from agricultural areas.[120b]

Metam sodium: Use results in many acute poisonings and high seasonal exposures

Metam sodium is a dithiocarbamate pesticide used to fumigate soils before planting carrots, tomatoes, potatoes, and other crops. In 2000, 12.8 million pounds were applied in California. Use is heaviest in Kern, Fresno, Imperial, Los Angeles, and Santa Barbara counties (see map on page 26).

Metam sodium is a developmental toxicant and probable carcinogen. When combined with water in the soil, it breaks down into the highly toxic and volatile methyl isothiocyanate (MITC), which then breaks down to form smaller quantities of the highly toxic gases hydrogen sulfide (H_2S) and methyl isocyanate (MIC)—the gas that killed tens of thousands in Bhopal, India, due to a Union Carbide chemical plant leak in 1984. These gases are extremely irritating to the eyes and respiratory system (Table 2-2). A metam sodium drift poisoning incident study conducted after a train derailment spilled 19,000 gallons into the Sacramento River at Dunsmuir in 1991 indicates that exposure to metam breakdown products may both cause and exacerbate asthma and other respiratory problems.[162]

In a risk assessment finalized in August of 2002, DPR determined the acute REL for MITC to be 66,000 ng/m^3.[132] Because the toxic endpoint is eye irritation and not a systemic effect, the adult and child REL are the same. The sub-chronic REL for MITC was determined to be 3,000 ng/m^3 (1 ppb) for adults. We calculated a sub-chronic REL of 1,300 ng/m^3 (0.44 ppb) for a one-year-old child (see Appendix 2 for details on calculation of RELs). These RELs do not include an additional uncertainty factor to take into account the particular vulnerability of children to toxic substances.

ARB, DPR and the chemical manufacturer have conducted six application site monitoring studies for metam sodium under a variety of application conditions, not all of which are still permitted in California. Figure 2-2 shows results from a sprinkler application of metam sodium to a 20-acre field in Kern County in August of 1993 under currently legal application conditions.[163a] This study was designed to capture a worst-case scenario—sprinkler application at high temperatures, low humidity, and high application rate. The plots show the results in terms of measured concentrations of MITC in air over time for sampling sites both upwind and downwind of the field at several distances from the field border (see Appendix 3 for the full data set).

The maximum concentration of 7,326,000 ng/m^3 —111 times the adult and child acute REL—was observed during the six-hour application period

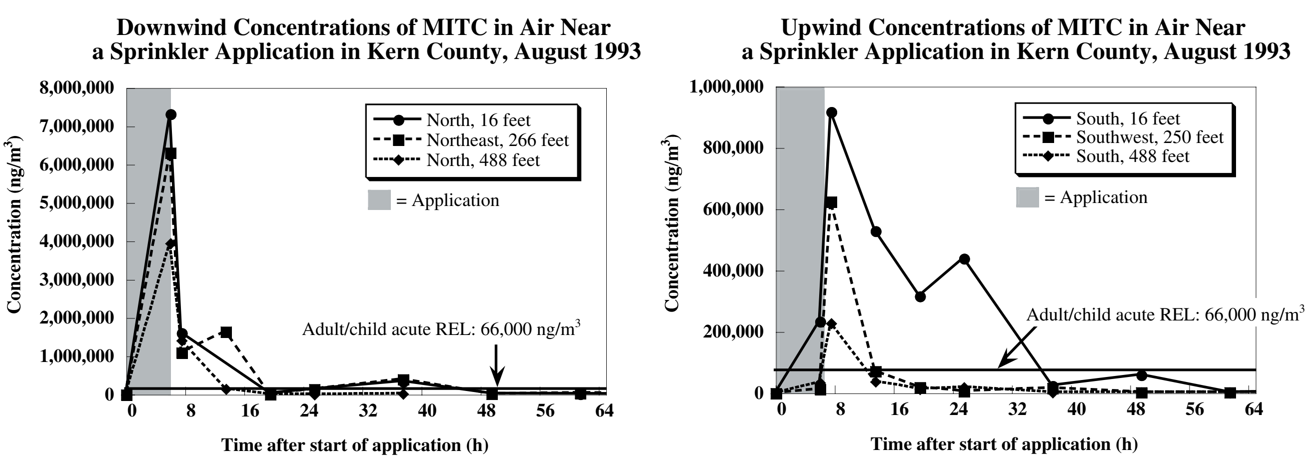


Figure 2-2
Peak MITC concentrations downwind from the field border in Kern County in August 1993 reached up to 7,326,000 ng/m^3, and ranged from 60 to 111 times the acute REL for a one-year-old child, depending on distance from the field. Upwind concentrations also exceeded the acute REL.
Source: Reference 163.

at a site 16 feet from the downwind edge of the field. Concentrations decreased only slightly with distance. At 488 feet downwind, a concentration of 3,947,000 ng/m^3 was observed—60 times the adult and child acute REL. Upwind concentrations also exceeded RELs. For the upwind site closest to the field, the peak concentration of 918,000 ng/m^3 exceeded the acute REL by a factor of 14. The three-day average concentration at the northeast sampling site 266 feet from the field boundary was 21 times the acute REL.

A review of other DPR, ARB, and chemical industry application site monitoring studies[132, 164] indicates that the sprinkler application discussed above represented a worst-case scenario application conducted according to label instructions. Concentrations could be substantially higher if the application is not done correctly. The lowest peak concentration was measured in an ARB study conducted under conditions of cool soil and air temperatures, high humidity, and low application rate (about 20% of the application rate for the sprinkler application discussed above) at 242,000 ng/m^3 (3.7 times the acute REL) 45 feet from the field boundary. See Table A-6 in Appendix 3 for summary application site monitoring data from these other studies.

A few application site monitoring studies have been designed to detect the MITC breakdown products MIC and H_2S.[132] Neither U.S. EPA nor DPR have set acute RELs for MIC, but OEHHA has published an adult acute REL for H_2S of 1,000 ng/m^3.[165] The concentrations of H_2S measured near the sprinkler application discussed above ranged from 51,000 to 177,000 ng/m^3 during the first sampling period, 51 to 177 times the acute REL. A different study found MIC in 100% of the samples, ranging from 200 to 5,800 ng/m^3.

Both indoor and outdoor seasonal ambient air monitoring was conducted for MITC in May through August 1997 and in January and March 1998 at Kern County sites somewhat distant from applications but in high-use regions.[166] Because monitoring took place over several months, the data serve as an estimate of sub-chronic exposure (see Figure 2-3). Observed concentrations were higher in summer than winter due to higher use, higher temperatures, and lower humidity.[167] Indoor concentrations were not necessarily lower, and were sometimes higher than corresponding outdoor samples. The highest average concentration—in the summer at a Weedpatch outdoor monitoring station—exceeded the adult sub-chronic REL by a factor of 1.4 and the sub-chronic REL for a one-year-old child by a factor of 3.2. Over 75% of the samples collected in the summer of 1997 had measurable concentrations of MITC. ARB conducted seasonal ambient monitoring in 2001 in Kern, Santa Cruz, and Monterey counties, but results have not yet been released.

The list of poisoning incidents related to metam sodium use is extensive. The 1997 Earlimart sprinkler application episode described on page 15 is the worst documented drift poisoning from agricultural use of metam sodium, but there are many others (see Table 2-4, p. 30). A majority resulted from sprinkler applications, a particularly hazardous way to apply this pesticide. Most recently, at 5:30 a.m. on June 6, 2002, 138 workers tending a large vineyard near Bakersfield complained of a strong odor and eye and throat irritation. A metam sodium sprinkler application had just been completed on a carrot field 100 feet away. State and county officials concluded that the applicator had violated label requirements by failing to stop the application and seal the treated soil when strong odors occurred during application. The grower had also failed to post the field under fumigation.[168]

Soil injection applications of metam sodium have also caused drift poisonings. At 9 p.m. on July 8, 2002, residents of the Kern County town of Arvin

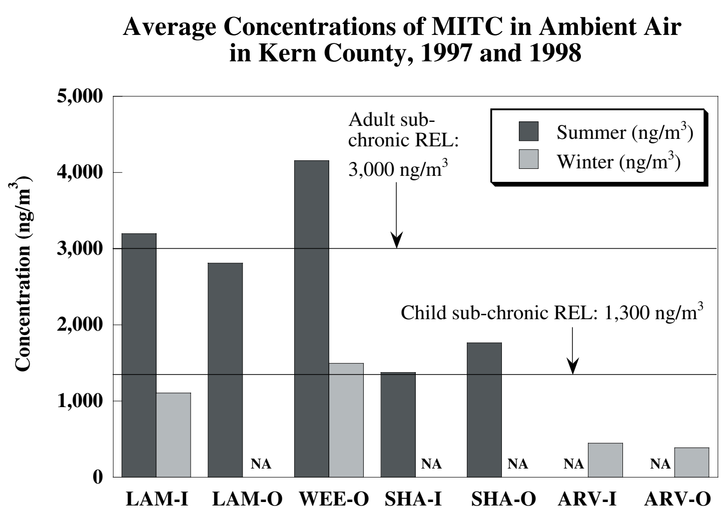


Figure 2-3:
Seasonal MITC ambient air levels measured both outside and in homes in 1997 and 1998 in Kern County in summer and winter exceeded both adult and child sub-chronic RELs at most locations. Monitoring sites are: LAM-I, Lamont—indoors; LAM-O, Lamont—outdoors; WEE-O, Weedpatch—outdoors; SHA-I, Shafter—indoors; SHA-O, Shafter—outdoors; ARV-I, Arvin—indoors; ARV-O, Arvin—outdoors. Only summer samples were taken in Shafter and only winter samples in Arvin. NA = not available.
Source: Reference 132.

Table 2-4: Metam Sodium/ MITC Drift Poisoning Incidents

County	Year	Application Method[a]	Distance to Injured	Comment
San Joaquin	1993	Shank injection	2 miles	Five residents reported eye irritation, itching, sore throat, and headaches.
San Joaquin	1995	Sprinkler	0.13 miles	Fourteen workers at a manufacturing plant developed eye and respiratory symptoms. An inversion layer was present at the time of the incident.
San Joaquin	1995	Sprinkler	0.51 miles	Eight California Youth Authority workers and 11 wards developed eye and respiratory symptoms.
San Joaquin	1995	Sprinkler	0.85 miles	Six manufacturing plant employees exposed 42 days earlier developed eye and respiratory symptoms.
San Joaquin	1996	Sprinkler	0.8 miles	Eleven California Youth Authority workers noticed odor and developed eye irritation.
Fresno	1996	Shank injection	0.13 miles	Twenty-eight students and one adult waiting for a bus developed eye irritation and other symptoms.
Kern	1997	Shank injection	up to 0.2 miles	Thirty-eight people experienced eye and respiratory irritation and aggravation of preexisting asthma.
Santa Barbara	1999	Sprinkler	0.8 miles	Twenty-two workers and children at an auto shop and elementary school reported nausea, eye irritation, and sore throats.
Tulare	1999	Sprinkler	0.4 to 1.08 miles	A total of 173 Earlimart residents reported eye and respiratory irritation and asthma aggravation. Some are still affected.
Kern	2002	Sprinkler	100 feet to 0.5 miles	A crew of 138 vineyard workers reported eye and throat irritation and one worker developed nausea
Kern	2002	Shank injection	513 feet	Over 260 Arvin residents reported symptoms including eye irritation, nausea, vomiting, and breathing difficulties (investigation not yet final).

Sources: See references 168, 170 and 171.

a. Application methods: In shank injection applications, metam sodium is injected into the soil through metal tubes called shanks and water is applied to seal the soil. In sprinkler applications, metam sodium is mixed into water applied to the field through sprinklers and then additional water is applied to seal the soil.

contacted the fire department after smelling a foul odor and experiencing eye and respiratory irritation. State and county officials concluded that drift occurred because the applicator delayed watering after injecting metam sodium into the soil.[169]

1,3-Dichloropropene (Telone): Chronic exposures pose cancer risk

Telone is a chlorinated pesticide used to fumigate soil before planting, and is primarily used on carrots, sweet potatoes, and wine grapes. In 2000, 4.4 million pounds were applied in California, predominantly in Merced, Kern, Fresno, Stanislaus, and Monterey counties (see map on page 26). Telone is strongly irritating to the eyes and respiratory tract, and U.S. EPA classifies it as a probable carcinogen.

DPR determined the adult acute REL for Telone to be 404,000 ng/m^3.[134b] We calculated an acute REL of 175,000 ng/m^3 for a one-year-old child (see Appendix 2 for details on calculation of RELs). DPR's adult sub-chronic REL is 276,000 ng/m^3, and child sub-chronic REL is 120,000 ng/m^3. These RELs do not include an additional uncertainty factor to take into account the particular vulnerability of children to toxic substances.

ARB has conducted both application site and seasonal ambient air monitoring studies for Telone (see Appendix 3 for the full data set).[172] Figure 2-4 shows the results of a study conducted under currently legal application conditions in Monterey County in September 1993, in terms of measured air concentrations of 1,3-dichloropropene over time for sampling sites 300 feet from the field border (see Appendix 3 for the full data set).

The peak measured concentration of 62,000 ng/m^3 (over 11 hours) was 15% of the adult acute REL and 35% of the acute REL for a one-year-old child at a distance 300 feet from the field boundary. With the present RELs that do not include an additional uncertainty factor to protect children, it does not appear that a similar application would pose an immediate health risk to people 300 feet from the field. Concentrations 100 feet from the field (a buffer zone currently allowed) will be somewhat higher, but were not measured in this study. A more significant risk posed by exposures to 1,3-dichloropropene at these concentrations is carcinogenicity, a delayed but severe chronic impact. We discuss the 1,3-dichloropropene contribution to elevated cancer risks below.

The 1993 Monterey County application site study is the only one available for Telone for currently legal application conditions, but was not designed to capture a worst-case legal application scenario. The fumigant was applied at less than half the maximum application rate of 225 lbs/acre and was injected to 18 rather than the minimum permissible 12 inches. Additionally, label and permit conditions allow a smaller buffer zone of 100 feet every third year, but this study did not evaluate concentrations at that distance. However, during the sampling period the wind did blow in predominantly one direction (from the southeast), resulting in a worst-case downwind exposure scenario for this type of application.

ARB conducted seasonal ambient air monitoring for Telone in 2000 and 2001, with monitoring stations at sites somewhat distant from direct applications but in regions of high use during the peak fumigation season.[173] Kern County sites were selected primarily for proximity to areas of high Telone use, but Monterey and Santa Cruz sites were chosen for proximity to areas of high methyl bromide use and may not have been located in areas with highest Telone use.

Using historic pesticide use information and assuming continued use at the 2000 level, we can estimate chronic lifetime exposure to 1,3-dichloropropene and its associated cancer risk (see Appendices 2 and 3 for details). As Table 2-5 (next page) and Figure 2-5 show, excess cancer risk from lifetime (70 year) exposure at average Kern County air levels exceeds the one in one million and even less-protective ten in one million standard using either 2000 or 2001 as the base year . Measured concentrations increased substantially at several coastal sites between 2000 and 2001, but decreased at some Kern County sites, probably due to altered use patterns in the area nearest monitoring stations. Telone use was substantially higher in Merced County in 2000, but no monitoring was done there.

Cancer risk varies depending on exposure, and different populations are exposed to varying degrees. For the top 25% of the most heavily exposed population, a recent analysis estimated cancer risk from

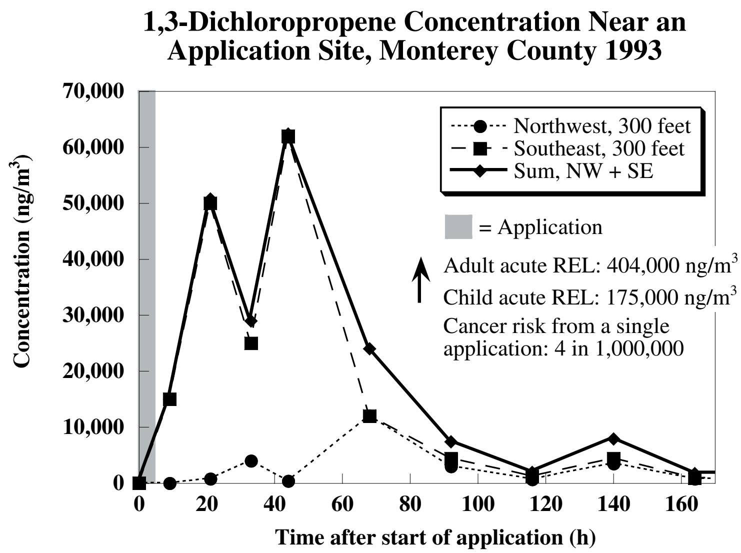


Figure 2-4

Telone concentrations remain below both adult and child acute RELs. However, cancer risk for chronic exposures exceeds acceptable levels.

Source: Reference 172.

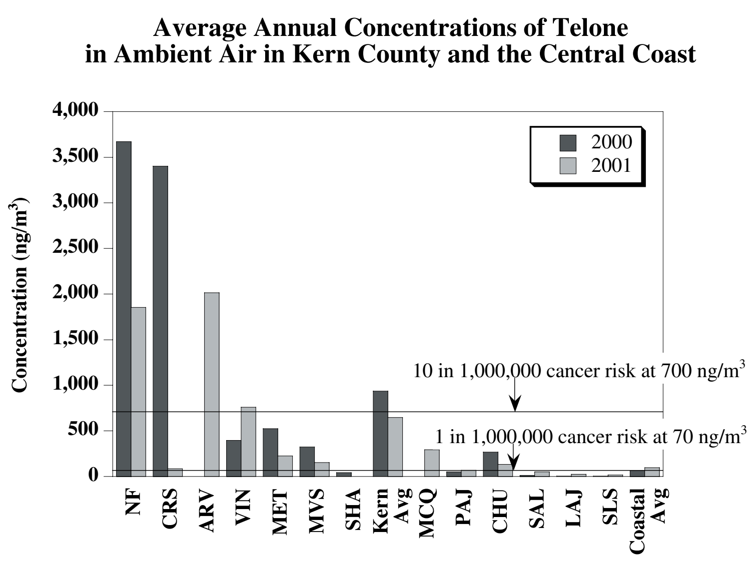


Figure 2-5

Seasonal ambient air levels of 1,3-dichloropropene, adjusted to annual average air concentrations (see Appendices 2 and 3), exceed the cancer risk of one in a million by a factor ranging from 1.1 to 56 in 2001. Kern monitoring sites include CRS, the Cotton Research Station in Shafter; ARV, Arvin High School; VIN, Vineland School near Arvin; MET, Mettler Fire Station; MVS, Mountain View School in Lamont; SHF, Shafter Air Monitoring Station. Monterey and Santa Cruz monitoring sites include MCQ, MacQuiddy School near Salinas; PAJ, Pajaro Middle School near Watsonville; CHU, Chular School in Greenfield; SAL, downtown Salinas; LJS, La Joya School in Salinas; SEL, Salsepuedes School in Watsonville. Air levels are also shown for Near Field (NF), an estimate of exposure at a home 300 feet from a fumigated field in a high use area.

Source: Reference 173.

Table 2-5: Estimated Lifetime Cancer Risks from Exposure to 1,3 Dichloropropene at Concentrations Measured in 2000 and 2001

Air Monitoring Site	Estimated Lifetime Cancer Risk, Expressed as a Probability per Million People, Assuming Lifetime Exposures at Levels Measured in 2000[a]	Estimated Lifetime Cancer Risk, Expressed as a Probability per Million People, Assuming Lifetime Exposures at Levels Measured in 2001[a]
Kern County sites		
Living 300 feet from field in a region of high use (NF)[b]	56	28
Cotton Research Station—Shafter (CRS)	52	1.3
Arvin High School (ARV)	not tested	24
Vineland School (VIN)	6.1	12
Mettler Fire Station (MET)	8.1	3.6
Mountain View School (MVS)	5.0	2.4
Shafter Air Monitoring Station (SHF)	0.6	not tested
Average of Kern County sites	**14.4**	**8.8**
Central Coastal sites		
MacQuiddy School (MCQ)	not tested	4.5
Pajaro Middle School (PAJ)	0.8	1.0
Chular School (CHU)	4.1	2.1
Salsepuedes School (SAL)	0.2	0.8
La Joya School (LJS)	0.1	0.4
Salinas downtown (SAL)	0.1	0.3
Average of Central Coast sites	**1.0**	**1.5**

a. For comparison, in Merced County in 1990, the estimated cancer risk associated with lifetime exposure at the average 1,3 dichloropropene level was 92 in one million.

b. Risk estimates for those living within 300 feet of a fumigated field assume annual ambient air exposure at the highest average level measured (CRS in 2000 and ARV in 2001) plus three days of near-field exposure. Three days of exposure 300 feet from a fumigation by itself carries a risk of 4.2 in 1,000,000 excess cancers. See Appendices 2 and 3 for further details.

lifetime exposure to 2000 Kern air levels at two in one million additional cancer cases. For the top 5%, the risk increased to twenty in one million.[106]

Chloropicrin: Use on the rise

Chloropicrin is a highly toxic pesticide used both alone and with methyl bromide or 1,3-dichloropropene (Telone) to fumigate soil prior to planting strawberries, tomatoes, and nursery crops. It is also used with the structural fumigant sulfuryl fluoride as a warning agent. In 2000, 3.8 million pounds were applied in California, with heaviest use in Monterey, Ventura, Santa Cruz, Santa Barbara, and Orange counties. Chloropicrin—a component of tear gas—is severely irritating to the eyes and respiratory system, and toxicology studies indicate it can cause chronic damage to lung bronchioles. As Figure 2-1 on page 24 shows, use has increased over the last few years. Strawberry growers have begun to use methyl bromide-chloropicrin mixtures with higher percentages of chloropicrin so they can use smaller buffer zones. Sometimes pure chloropicrin is used to fumigate field perimeters.

In 2001, ARB conducted seasonal ambient air monitoring for chloropicrin in Kern, Monterey, and Santa Cruz counties at sites where other fumigants were being monitored. Results are expected to be available in 2003.

PAN archive

Telone is applied by shank injection into bare soil. In the left photo, the shanks are visible below the barrels. In the right photo, the shanks are underground, dispensing Telone.

Recent DPR or U.S. EPA chloropicrin risk assessments are not yet available, but OEHHA has determined acute and chronic RELs that can be used to assess exposure data when it is released. OEHHA's adult acute REL is 35,200 ng/m^3 (4.4 ppb)[174] and adult chronic REL is 0.05 ppb (400 ng/m^3).[175] No sub-chronic RELs have been determined for this chemical.

DPR has not yet issued a recommended buffer zone for chloropicrin, but County Agricultural Commissioners from the southern counties[176] have adopted chloropicrin permit conditions that specify buffer zones of 100–300 feet between treated fields and residences and worksite buffer zones of 30–150 feet, depending on acreage treated and application method. While these counties are to be commended for their initiative, the adequacy of these buffer zones is questionable. Levels of chloropicrin that far exceed the OEHHA acute REL have been measured at least 180 feet from fumigated fields and greenhouses.[177] This raises serious concerns about respiratory health effects because of evidence that long-term exposure can damage the lungs. Such concerns have prompted DPR to initiate a reevaluation of chloropicrin, and manufacturers are being required to conduct worker exposure and air monitoring tests.[178]

Sulfuryl fluoride: An urban drift hazard

Sulfuryl fluoride (Vikane™ and ProFume™) is a highly acutely toxic gas used predominantly in structural fumigations. Typically, the structure to be fumigated is sealed with tarps or by other measures and the gas released inside. After 24–70 hours, the structure is vented to the outside air using blowers or fans. This pattern of use makes sulfuryl fluoride one of the major causes of toxic pesticide drift in urban settings. Sulfuryl fluoride fumigations were responsible for 24 reported cases of poisoning in California in the last 5 years.[7] No monitoring data are yet available from ARB for this fumigant, but studies are underway to evaluate bystander exposure when tarps are removed from fumigated structures.

U.S. EPA completed its risk assessment for sulfuryl fluoride in 1992.[179] The compound is acutely toxic and is transformed into the highly corrosive hydrofluoric acid on contact with water or mucous membranes like those in the nose, throat, and lungs. It is also neurotoxic, causing tremors, nausea, and incoordination at higher doses. The risk assessment documents several sulfuryl fluoride poisoning deaths, and chronic worker exposures were cited as an issue for which insufficient data were available to fully assess risks. A Dow multigenerational rat study found developmental and reproductive toxicity, but did not report the statistical significance of the results.[180] U.S. EPA requested no further studies. The 5 part per million (ppm) post-fumigation level in air that U.S. EPA considers acceptable does not take into account the neurotoxic effects of the compound, only the acute respiratory effects for adults. Because this pesticide was evaluated prior to passage of the Food Quality Protection Act, no uncertainty factor for the special vulnerabilities of children is used to set acceptable re-entry levels. Still, U.S. EPA recommends (but does not legally require) that the level be below 2 ppm in homes with children. No safety recommendations protect people in neighboring homes and workplaces against the substantial drift from the venting of fumigated structures.

Of particular concern to residents of recently fumigated structures is that some materials—mattresses, pillows, cushions, polystyrene insulation, and other items—trap and then only slowly release sulfuryl fluoride gas.[179] Studies indicate that off-gassing can continue for up to 40 days after a fumigation, leading to low-level sub-chronic exposure.

With phaseout of methyl bromide on the horizon, Dow AgroSciences, manufacturer of sulfuryl fluoride, is aggressively pursuing new markets. The chemical has recently been temporarily approved for use as a commodity fumigant for walnuts and raisins.[181] Other uses are being developed as well, including fumigation of other nuts and dried fruits, as well as stored grains.[182] Dow plans to triple production capacity at its Pittsburg, California plant to meet anticipated demand. Soil fumigation is not a planned use because of the fumigant's high mobility.

U.S. EPA evaluates methyl iodide as a possible methyl bromide replacement

U.S. EPA is presently evaluating methyl iodide as a replacement for methyl bromide, with the decision on whether to register this chemical scheduled for 2003.[183] Growers are pressuring DPR to allow use of the chemical in California if it is registered by U.S. EPA.

Methyl iodide is chemically related to methyl bromide, but more reactive and thus not an ozone layer threat.[184] However, because of its greater reactivity, it also reacts readily with biomolecules like DNA, the genetic material in cells. The chemical is listed as a carcinogen under California's Proposition 65 statute. A neurotoxicant, it also targets the lungs, liver, and kidneys. Symptoms of poisoning from inhalation include dizziness, sleepiness, nausea, diarrhea, slurred speech, incoordination, and muscle convulsions.[185] Methyl iodide has approximately the same acute toxicity as methyl bromide, but about twice that of 1,3-dichloropropene.[186] Neither U.S. EPA nor DPR have set an REL for this chemical, but the National Institute of Occupational Safety and Health has set an eight to ten-hour worker (adult male) exposure limit of 10,000,000 ng/m^3.[187]

Because methyl iodide is highly volatile, it is as drift-prone as other fumigants. A study of methyl iodide-treated soils demonstrated that cumulative volatilization losses from sandy loam soils ranged from 94% of the amount applied in untarped soils to 75% in soils covered with high-barrier tarps.[188] Tarping increased downward movement of the pesticide, which increased leaching into groundwater. The half-life of methyl iodide in soil depends on soil type, from 42 to 63 days for sandy loam soils and 9 to 13 days in soils rich in organic matter.[189]

Drift from high-use insecticides and herbicides poses a particular hazard to children

This section presents air monitoring data for five high-use insecticides and herbicides. The acute and sub-chronic toxicities of these pesticides are so high that even very low air concentrations put exposed people, especially children whose nervous and immune systems are still developing, at risk of ill effects. Airborne exposures are just a part of the picture, since people are commonly exposed to residues of these same pesticides in food, on surfaces in homes, and in drinking water. Some of these pesticides are in the same chemical family, and therefore have a common mechanism of toxicity. Exposure to multiple pesticides with the same mechanism of toxicity results in additive toxic effects.

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Spray drift from pesticide applications is the most visible form of drift, but invisible post-application drift often exceeds "acceptable" levels.

For example, two pesticides profiled in this section, diazinon and chlorpyrifos, are neurotoxicants belonging to the class of insecticides known as organophosphorus (OP) pesticides. All chemicals in this class poison the nervous system by the same mechanism—blocking the action of cholinesterase, an enzyme necessary for proper transmission of nerve impulses. Twenty-nine of these OP pesticides are registered for use in California, and approximately 20 are currently used on crops, in homes, or on lawns. The multiple uses and ubiquitous nature of these chemicals result in routine exposures to many different OP pesticides for most people. The U.S. Centers for Disease Control (CDC)[190] and several academic scientists[191] have recently documented widespread OP exposure, revealing that most people in the U.S. have breakdown products of these pesticides in their urine.

U.S. EPA is presently conducting a cumulative risk assessment for OP pesticides and several other chemical groups,[144] but has failed to comprehensively assess exposure routes. Thus, airborne exposures for residents and bystanders from agricultural uses are routinely dismissed as unimportant (see Chapter 3, page 47).

U.S. EPA's assessment of exposures resulting from residential uses of diazinon and chlorpyrifos resulted in cancellation of all residential uses of these pesticides. Data shown below suggest that canceling or severely restricting agricultural uses of these chemicals will be required to effectively protect human health.

Chlorpyrifos: Near-field exposures pose risk of neurotoxicity to children

Chlorpyrifos is an organophosphorus insecticide used for structural pest control and for agricultural applications on cotton, oranges and almonds. Also known as Dursban (residential use products) or Lorsban (agricultural), among other trade names, it is one of the most widely used insecticides in the U.S., both in agriculture and in and around the home.[192] In California in 2000, 2.4 million pounds were sold, with 2.1 million pounds reported used in non-consumer applications.[1,2b] Fresno County has the highest reported agricultural use, followed by Kern, Tulare and Kings counties (see map, page 26).

Chlorpyrifos is neurotoxic, inhibiting acetyl cholinesterase, an enzyme necessary for proper transmission of nerve impulses. It is a developmental neurotoxicant, with low concentrations causing a reduction in the development of neural connections in fetal rats.[137] It is also a suspected endocrine disrupting compound; moderate doses have been shown to alter hormone levels in animal studies.[193]

This insecticide was widely used in consumer products until U.S. EPA found high risks to children in the home. They reached an agreement with the companies who market it to phase out all homeowner use products by the end of December 2001.[192] Certified professional or agricultural applicators may still use the chemical in homes, but uses that pose the most immediate risks to children—including home lawn use, indoor crack and crevice use, and whole-house, post-construction termiticide treatments—were canceled as of the end of 2001. All products for pre-construction treatments will be phased out by the end of 2005. U.S. EPA estimates that these uses account for about 50% of the total nationwide. Major agricultural uses altered by this phaseout agreement include elimination of use on tomatoes and changes in use patterns for apples and grapes to reduce residue levels.

In a risk assessment finalized in 2002,[137] U.S. EPA determined an "acceptable" dose for chlorpyrifos inhalation exposures of 0.1 milligrams per kilogram of body weight per day (mg/kg-day), which translates into an adult REL of 3,880 ng/m^3 and 170 ng/m^3 for a one-year-old child (see Appendix 2 for details on calculation of RELs). Sub-chronic and acute RELs are the same for this pesticide. These values include an additional uncertainty factor of 10 to allow for the particular vulnerability of children to toxic substances.

In California, the peak season for agricultural chlorpyrifos use is June through September in the Central Valley. In June 1996, ARB conducted an air monitoring study for a chlorpyrifos application to a Tulare County orange grove (see Appendix 3 for details).[194] The study monitored both chlorpyrifos and its breakdown product chlorpyrifos oxon. Below, we evaluate only the chlorpyrifos data because no RELs have been set for chlorpyrifos oxon, although it is known to be more acutely neurotoxic.

Figure 2-6 shows monitoring results in terms of measured air concentrations of chlorpyrifos over time for sampling sites approximately downwind of the grove (see Appendix 3 for the full data set).

Because of high winds, the application was stopped after about half of the trees were sprayed. The application was completed the next day, with lighter winds coming from a different direction. Air concentrations peaked at 30,950 ng/m^3 at the east downwind site 30 feet from the field boundary during the 2.5 hour sampling period after completion of the first application,[195] exceeding the adult REL by a factor of 8 and the child REL by a factor of 184. A slightly lower peak concentration of 27,700 ng/m^3 at 57 feet from the field boundary was observed during the second application on the north side of the field. High winds quickly cleared much of the chlorpyrifos out of the air between the two applications, but concentrations following the second application remained high much longer due to the lighter wind conditions.

Concentrations exceeded RELs in 95% of samples, with three-day averages ranging from 6,180 to 9,356 ng/m^3 (depending on the location of the monitoring station), 37 to 56 times the child REL and 1.6 to 2.4 times the adult REL. Concentrations of chlorpyrifos were still above both the adult and child RELs at the downwind site at the end of the monitoring period, at 4,900 ng/m^3 (29 times the child REL and 1.3 times the adult REL). These data indicate that those who live or work near application sites risk nervous system toxicity from airborne exposure to this pesticide. Infants and children are

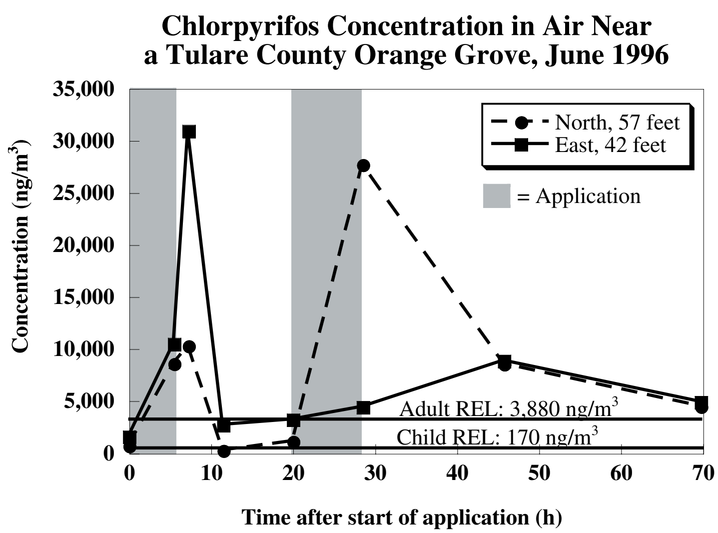


Figure 2-6
Chlorpyrifos air concentrations peaked approximately 2.5 hours after the end of the first application and again during the second application, with maximum concentrations on the downwind side of the orchard exceeding the adult REL by a factor of 8 and the child REL by a factor of 184. Off-gassing continued for several days after application and exceeded RELs for both adults and children for most of the sampling period.
Source: Reference 194.

especially at risk because their nervous systems are still developing.

There is only one application site monitoring study available for chlorpyrifos; however, the fact that the application occurred in two distinct time periods provides essentially two applications in one study. The similar peak concentrations observed for the two applications under different wind conditions (30,950 ng/m^3 vs. 27,700 ng/m^3) suggest that peak air concentrations may be quite predictable. The breakdown product chlorpyrifos oxon was observed in 100% of the samples, but not taken into account in this analysis. However, because the oxon is more acutely toxic than the parent compound, neurotoxic effects associated with breathing air contaminated with both chlopyrifos and its oxon at the measured levels will be greater than chlorpyrifos concentrations alone indicate.

ARB also sampled seasonal concentrations of chlorpyrifos in ambient air by placing monitoring stations on several schools somewhat distant from direct applications but in regions of high use (see Appendix 3 for full data set). Monitoring occurred in June over four and a half weeks, which serves to estimate sub-chronic exposure (see Figure 2-7). For chlorpyrifos, acute and sub-chronic RELs are the same. Average concentrations were below both adult and child RELs over the time frame of the monitoring study, averaging 38% of the one-year-old child REL over all sites. The maximum measured 24-hour concentrations equaled or exceeded the child REL at four of the five monitoring sites and ranged from 0.23 to 4.8 times the child REL, concentrations that may have neurotoxic effects in some children. Because chlorpyrifos is also present as residues on foods, and because other OP pesticides with a similar mechanism of action are also used on foods and present in the air, aggregate exposures will be higher for some individuals.

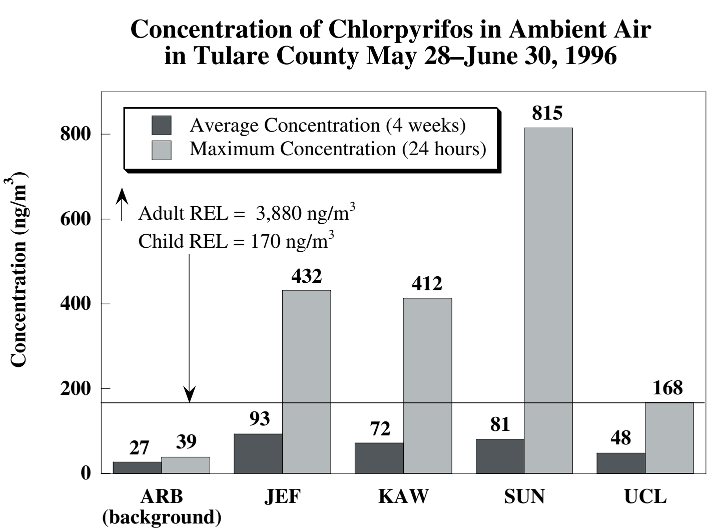


Figure 2-7

Four-and-a-half-week average chlorpyrifos concentrations in ambient air in Tulare County ranged from 16 to 55% of the REL for a one-year-old child. Concentrations occasionally exceeded the child REL during a 24-hour monitoring period, with the maximum 24-hour concentration at each site ranging from 23 to 485% of the REL. Monitoring sites included ARB, the ARB office in downtown Visalia; JEF, Jefferson Elementary School in Lindsay; KAW, Kaweah School in Exeter; SUN, Sunnyside Union Elementary School in Strathmore; UCL, University of California, Lindcove Field Station.

Source: Reference 194.

Diazinon: Near-field exposures pose risk of neurotoxicity to children

Diazinon is an organophosphorus insecticide applied to a wide variety of fruits, nuts, and vegetables, as well as in structural pest control. In California in 2000, 1.4 million pounds were sold, with one million pounds reported used in non-consumer applications.[1,2b] Monterey County has the highest reported agricultural use of this pesticide, followed by Fresno, Stanislaus, Tulare and Imperial counties (see map on page 26).

Diazinon is neurotoxic, inhibiting acetyl cholinesterase, an enzyme necessary for proper transmission of nerve impulses.[139] It is also a developmental toxicant at higher doses, resulting in reduced litter sizes and fewer live offspring in rats.[152] Because diazinon has the same mechanism of action as chlorpyrifos, it may also be a developmental neurotoxicant, but no studies to test for this possible outcome are publicly available at present.

Diazinon was widely used in consumer products, but after U.S. EPA found high risks to children in the home, they reached an agreement with the manufacturer, Syngenta, to phase out all products for indoor residential uses by the end of December 2002, and for outdoor home lawn care by the end of 2004.[196] U.S. EPA estimates that these uses account for about 70% of the total nationwide. While this phaseout agreement eliminated a few agricultural uses, most major agricultural uses in California (almonds, peaches, plums, nectarines, lettuce) were unaffected.

In a risk assessment finalized in 2002,[139] U.S. EPA determined an "acceptable" dose for diazinon inhalation exposure of 0.026 mg/kg-day, which translates into an adult REL of 330 ng/m^3 and that for a one-year-old child of 145 ng/m^3 (see Appendix 2 for details on calculation of RELs). The acute and sub-chronic RELs are the same for this pesticide, and do not include an additional uncertainty factor for the particular vulnerability of children to toxic substances.

In California, the peak season for agricultural use of diazinon is January and early February to kill over-wintering insects in dormant almond and stonefruit orchards in the Central Valley. In February 1998, ARB conducted an air monitoring study of a winter application to a Kings County peach orchard (see Appendix 3 for details).[197]

Figure 2-8 shows the results in terms of measured air concentrations of diazinon over time for the sampling site downwind of the orchard (see Appendix 3 for the full data set). The peak concentration of 5,500 ng/m^3, measured at the downwind site during a four-hour sampling period approximately eight hours after the application ended, was 16 times higher than the adult REL and 39 times higher than the REL for a one-year-old child. This measurement was taken 72 feet from the field boundary. Concentrations exceeded the child REL in 82% of the samples taken throughout the monitoring period, with three-day average concentrations ranging from 1,048 to 3,143 ng/m^3 (depending on the monitoring station location), 7.2 to 22 times the child REL and 3.1 to 9.4 times the adult REL. Levels remained above the RELs for both adults and children at the downwind site at the end of the sampling period, at 600 ng/m^3, or 4.1 times the child REL and 1.8 the adult REL. These data indicate that those who live or work near application sites risk nervous system toxicity from airborne exposure. Infants and children are especially at risk because their nervous systems are still developing.

This is the only application site monitoring study available for diazinon; however, it does not represent a worst-case exposure scenario. Because winds were light and variable during the sampling period, drift was fairly evenly distributed to all sides of the field. If the wind were blowing steadily from one direction, concentrations at the downwind site would be higher than those measured, with a peak concentration closer to that of the sum of all directions. The study also occurred in February, when temperatures are low. Concentrations will be higher at warmer temperatures.

ARB also sampled seasonal concentrations of diazinon in ambient air by placing monitoring stations on several schools somewhat distant from direct applications but in regions of high use (see Appendix 3 for full data set). Monitoring covered a three week period and serves to estimate sub-chronic exposure (see Figure 2-9 and Appendix 3). For diazinon, acute and sub-chronic RELs are the same. Average concentrations were below RELs during the study, averaging 15% of the one-year-old child REL over all sites. Maximum measured 24-hour concentrations exceeded the one-year-old child sub-chronic REL at one site, ranging from 20–110% of the

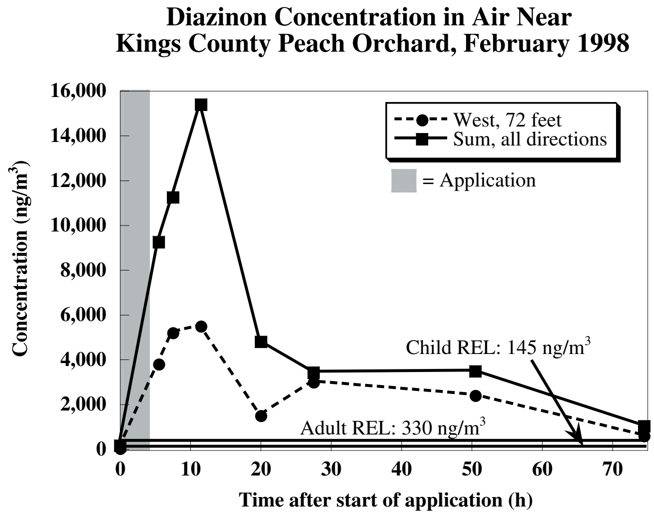


Figure 2-8

Diazinon air concentrations on the downwind side of a treated peach orchard exceeded the adult REL by a factor of 16 and the one-year-old child REL by a factor of 39 during the peak exposure period. Off-gassing continued for several days after application and exceeded RELs for both adults and children during the entire time period at the downwind site.

Source: Reference 197.

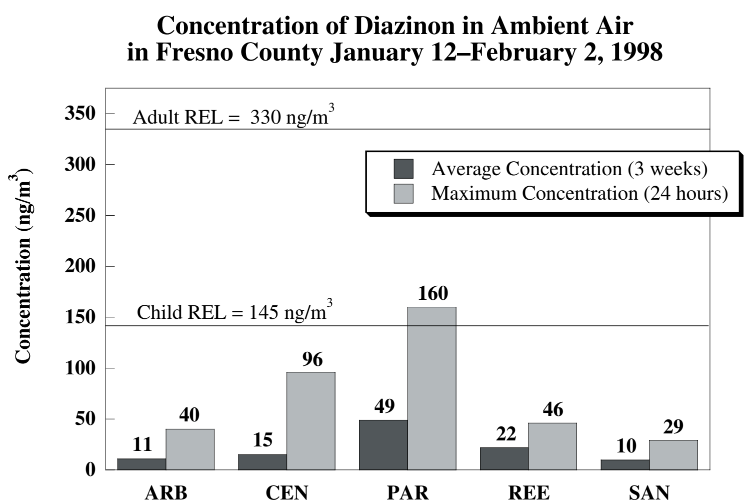


Figure 2-9

Three-week average diazinon ambient air concentrations in Fresno County remained below RELs for both adults and children. The child REL was exceeded at one site for one 24-hour sample. Monitoring sites included ARB, the ARB office in downtown Fresno; CEN, Centerville School; PAR, Parlier High School; REE, Kings Canyon Unified District Office in Reedley; SAN, Fairmont Elementary School in Sanger.

Source: Reference 197.

REL. Because diazinon is also present as residues on foods, and because other OP pesticides with a similar mechanism of action are also used on foods and present in the air, aggregate exposures will be higher for some individuals.

Molinate: High near-field and seasonal exposures pose risk of neurotoxicity and infertility to Sacramento Valley residents

Molinate is a thiocarbamate herbicide used almost exclusively in rice production to control watergrass. Syngenta, the primary manufacturer, sells it as Ordram® and Arrosolo®. Approximately 1.03 million pounds of molinate were used in California in 2000, almost exclusively in the Sacramento Valley (see map on page 26). Rice fields are treated with molinate either by tilling granules into the soil before rice seedlings are planted or by applying it to flooded fields during the growing season. Water from these fields is released into nearby waterways in late spring in the U.S., resulting in elevated molinate concentrations in local drinking water sources. Molinate is extremely volatile, resulting in extensive post-application drift.

This herbicide is toxic in many different ways.[140] A reproductive toxicant, molinate decreases the number of offspring and increases the percentage of abnormal sperm in exposed laboratory animals. Workers who mix, load, and apply it face serious fertility risks. A developmental neurotoxicant, it reduces response to stimuli at all dose levels tested in laboratory animals and reduces the size of some parts of the brain. U.S. EPA ranks molinate as a possible carcinogen, as it causes kidney tumors in laboratory animals.

Sacramento Valley: Bucolic or Toxic?

Over 2.1 million people live in the Sacramento Valley, California's primary rice-growing region and the location of most of the molinate use in the state. Approximately 660,000 of these people live where molinate use exceeds 100 pounds per square mile on a countywide basis. As Sacramento County has the least molinate use and greatest population, one might conclude that Sacramento residents are off the hook in terms of exposure. However, even in downtown Sacramento, at least seven miles from rice fields, the average ambient air concentration of molinate was found to be 13 ng/m^3 over several months—10% of the one-year-old child sub-chronic REL.[120a] At the Sacramento International Airport, the average seasonal ambient air concentration of molinate was found to be 49 ng/m^3, 38% of the REL, and the peak concentration for one week was measured at 370 ng/m^3. If Sacramento residents also drink molinate-contaminated Sacramento River water (some level of contamination is common during May and June), there is a reasonable expectation that their aggregate exposures could exceed RELs. The number of people potentially affected in California alone is 2.1 million, or 6.1% of the state's total population. Approximately 7% or 147,000 of these people are children under five.

In its preliminary molinate risk assessment, published in March 2002,[140] U.S. EPA determined the adult "acceptable" dietary acute dose of molinate to be 0.0006 mg/kg-day. Using standard methodologies, we converted this dietary dose into an adult acute inhalation REL of 23,300 ng/m^3 and a one-year-old child acute REL of 1,010 ng/m^3 (see Appendix 2 for details on calculation of RELs). Sub-chronic RELs were derived from an inhalation study and determined to be 3,000 ng/m^3 for adults and 130 ng/m^3 for a one-year-old child. These values include an additional uncertainty factor of ten to take into account the particular vulnerability of children.

In California, the peak season for molinate use is April through June. In May 1992, ARB conducted an air monitoring study for an application to a Colusa County rice field (see Appendix 3 for details).[198] As it is the only molinate application site monitoring study available, these data may or may not represent a worst-case exposure scenario.

Figure 2-10 shows the results of this study in terms of measured molinate air concentrations over time

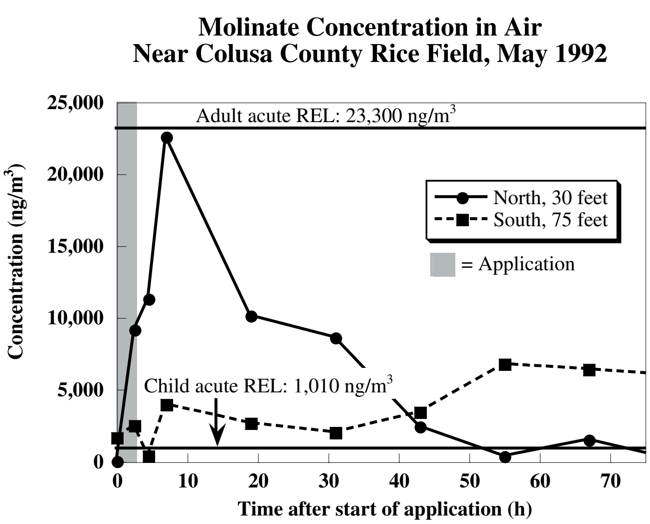
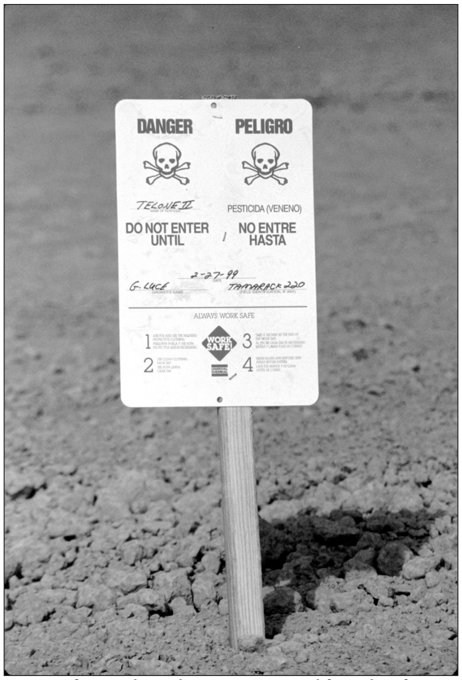


Figure 2-10
Molinate concentrations near a Colusa County rice field peaked at approximately 7 hours after the start of application, but remained above levels of concern for a one-year-old child for days after the end of the application.
Source: Reference 198.



PAN archive

Posting of pesticide applications is required for only a few pesticides. No prior notification of neighbors is required.

for sampling sites downwind of the field (see Appendix 3 for the full data set). The peak concentration of 22,610 ng/m^3, measured at the north downwind site approximately 5 hours after the application was complete, was 97% of the adult acute REL and 22 times higher than the acute REL for a one-year-old child. This measurement was taken 30 feet from the field boundary. Concentrations exceeded the child acute REL in 85% of near-field samples (North, 30 feet; South, 75 feet) taken throughout the monitoring period, with four-day averages ranging from 4,033 ng/m^3 to 6,953 ng/m^3 (depending on the monitoring station location), 4.0 to 6.9 times the child acute REL and 17% to 30% of the adult acute REL. At the end of sampling period, concentrations were still 6.2 times the one-year-old child acute REL 75 feet from the downwind edge of the field, at 6,270 ng/m^3.

Sampling stations one quarter mile from the field boundary showed lower concentrations, ranging from less than the limit of detection (approximately 250 ng/m^3) to 3.2 times the child acute REL (3,240 ng/m^3). Four-day averages ranged from 430 ng/m^3 to 1,159 ng/m^3, 42% to 114% of the one-year-old child acute REL, depending on location relative to the field. These data indicate that children who live near molinate applications may be at risk of nervous system and reproductive system toxicity from airborne exposure to this pesticide. Those living adjacent to fields are at particularly high risk.

ARB also sampled seasonal concentrations of molinate in ambient air by placing monitoring stations on fire stations in the Colusa County towns of Williams and Maxwell, somewhat distant from direct applications but in a region of high use. Monitoring covered a nine-day period and serves as an estimate of sub-chronic exposure (see Figure 2-11). Measured air concentrations ranged from 160 to 500 ng/m^3 in Williams, 1.2 to 3.8 times the one-year-old child sub-chronic REL; and from 400 to 1,170 ng/m^3 in Maxwell, 3.1 to 9 times the child sub-chronic REL. Averages over the nine-day period were 360 ng/m^3 in Williams and 724 ng/m^3 in Maxwell—2.8 and 5.6 times the child sub-chronic REL, and 12% and 24% of the adult sub-chronic REL. As Maxwell and Williams are on the west side of the Sacramento Valley, approximately 25 miles away from the area of highest molinate use (see map on page 26), it is likely that molinate air concentrations are substantially higher in or nearer to areas of greater use.

In a separate study, the U.S. Geological Survey (USGS) monitored ambient air in Sacramento County urban and suburban areas and found the average molinate concentration over two months to be 49 ng/m^3 at the Sacramento International Airport sampling site, 38% of the child sub-chronic REL.[120a]

Concentrations of Molinate in Ambient Air in Colusa County May 20-29, 1992

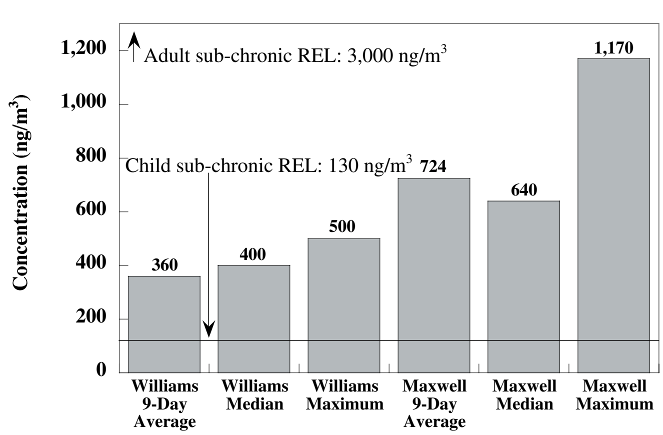


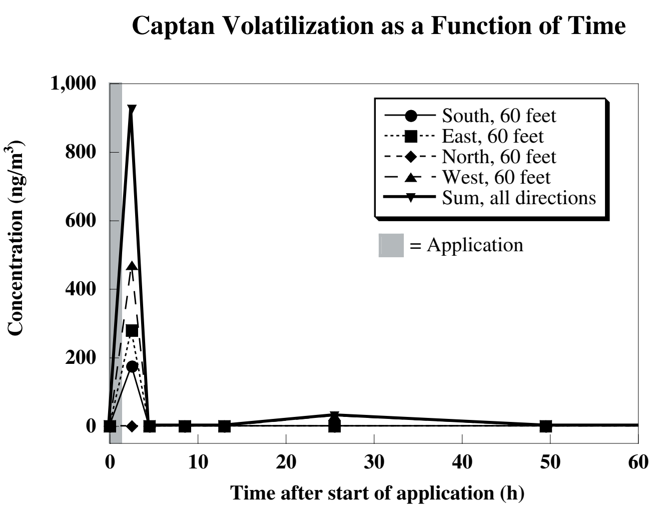
Figure 2-11

Nine-day average molinate concentrations in ambient air exceeded sub-chronic RELs for a one-year old child in towns near Sacramento Valley rice-growing areas. Because Williams and Maxwell are not in the region of highest molinate use, these measurements do not represent a worst-case scenario.

Source: Reference 198.

Spray drift is the primary transport mechanism for paraquat, propargite, and other non-volatile pesticides

Paraquat and propargite are both high-use pesticides with recent risk assessments and available air monitoring data. They differ from others discussed above in that they are not highly volatile. For this reason, the post-application drift that is so problematic for volatile pesticides is much less of a hazard for these non-volatile pesticides. ARB monitoring data for several of these pesticides demonstrate that the maximum concentration typically occurs during application, with negligible post-application volatilization drift (see Figure 2-12).[199]



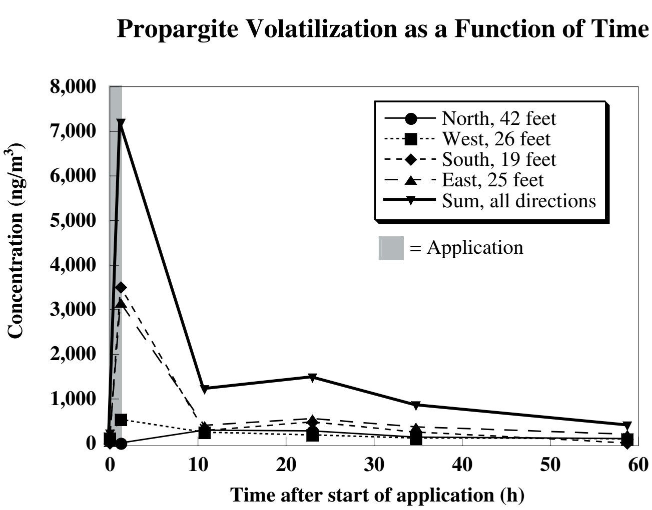


Figure 2-12

Air concentrations of non-volatile pesticides like propargite and captan peaked during application, as spray drift was trapped by the samplers. Application site monitoring data are not available for paraquat.

Source: Reference 199.

For these pesticides and others like them (see Table 2-6), the primary concerns are spray or dust drift that occurs during application, as well as windblown drift of contaminated soil. These contributions to drift are not insignificant, and some evidence links these exposures to disease. Recent analysis of the relationship between childhood cancer and agricultural pesticide use found elevated childhood leukemia rates in areas of highest propargite use, although no dose-response trends were found.[89] However, as detailed assessment of personal exposure to specific pesticides was beyond the scope of the study, impacts may have been masked by misclassification of each child's exposure status. The finding is highly suggestive, and merits follow-up research.

DPR monitoring of residues of propanil—a low-volatility herbicide used on rice in the Sacramento Valley—demonstrates that spray drift can travel for miles before settling.[200] Results indicate that aerial applications within 10 miles are correlated with a low background level of residues on the foliage of prune orchards. Aerial applications within six miles, or ground applications within one to two miles, are correlated with substantially higher residues. The data also show that when more pounds of pesticide are applied and more acres treated, higher residue levels result.

Multiple pesticides are frequently found in air samples

Ambient air monitoring data show that people frequently inhale many pesticides simultaneously.[120a, 148, 202] ARB/DPR and USGS designed several studies to look for multiple pesticides simultaneously, with monitoring stations located somewhat distant from pesticide applications. In two studies carried out in Lompoc, California, in 2000 and 2001, ARB/DPR looked for 28 different pesticides in air.[202] Most samples contained more than one pesticide, with the average containing six different pesticides. At least one sample contained 12 different pesticides. In a study of air in urban and suburban Sacramento in 1996 and 1997, USGS analyzed samples for 17 different pesticides.[120a] The maximum number detected in a single sample was six, even though use of most of the target pesticides was low near the immediate area of the monitoring stations. Diazinon, chlorpyrifos, and trifluralin were most commonly detected. Molinate and thiobencarb, rice herbicides, were detected at the highest levels, because of the proximity of rice fields and the chemicals' inherent volatility.

Table 2-6: Top Fifteen High-Use Non-Volatile Pesticides

Pesticide	Reported Use in 2000 (millions of lbs AI)[a]	Pesticide Volatility[b]	Air Monitoring Complete?[c]	Post-1996 Risk Assessment Available?	CA Bad Actor Pesticide?
Sulfur	62.9	Very low	No: Candidate TAC	No	No
Copper salts (sulfate, hydroxide)	8.22	Very low	None planned	No	No
Glyphosate, isopropylamine salt	4.64	Low	No: Candidate TAC	No	No
Sodium chlorate	2.52	Very low	None planned	No	No
Cryolite	1.96	Very low	No: Candidate TAC	No	No
Calcium hydroxide	1.90	Very low	None planned	No	No
Propanil	1.36	Low	None planned	No	No
Diuron	1.34	Low	No: Candidate TAC	No	Yes
Propargite	1.33	Low	Yes	2001, U.S. EPA[138]	Yes
Paraquat	0.98	Low	Ambient only[d]	1997, U.S. EPA[141]	Yes
Ziram	0.96	Low	Yes	No	Yes
Ethephon	0.74	Low	No: Candidate TAC	No	Yes
Simazine	0.70	Low	Yes	No	Yes
Urea dihydrogen sulfate	0.67	Very low	None planned	No	No
Captan	0.64	Low	Yes	1999, U.S. EPA[201]	Yes

a. Pesticide use data from 2000 DPR *Pesticide Use Reports*, reference 2b.

b. Volatility rankings are based on the vapor pressure (Vp) of the chemical at 20–25°C, an inherent physical property of the chemical that is a good predictor of whether a pesticide will drift off-site by volatilization after application. We rank pesticides using the following scheme: Very high—Vp $\geq 10^{-2}$; High—Vp between10^{-2} and 10^{-4}; Moderate—Vp between 10^{-4} and 10^{-6}; Low—Vp $\leq 10^{-6}$; Very low—Not measurable.

c. TAC = Toxic Air Contaminant. Chemicals listed as TAC candidates may be evaluated by DPR for listing as a TAC. See page 47 for more information about the TAC process.

d. No near-field, application site monitoring was conducted for paraquat.

It is easy to see why exposure to multiple pesticides is common. As an example of the extent of the problem, consider agricultural pesticide use in 2000 an area 18 miles by 18 miles near Earlimart, California in the Central Valley.[2b] Approximately 946,300 pounds of 224 different chemicals were applied in this area during 2000.[203] Of these pesticides, 60 were Bad Actors (see page 8), accounting for 279,500 pounds or 30% of the total applied. Applications were made on 323 days, with an average of 34 applications per day, and a maximum of 174 (in September). Bad Actor pesticides were applied on 278 days at an average rate of 11 applications per day.

ARB/DPR air monitoring in Lompoc and the USGS work in Sacramento both showed the presence of multiple pesticides in air. Yet most U.S. EPA and DPR risk assessments assume exposure to a single pesticide.[144] Health effects of exposure to the nearly limitless possible combinations of multiple pesticides and other air pollutants emitted from cars, trucks, and factories are too complex and variable to be known definitively. However, exposure to multiple chemicals is extremely unlikely to cause *fewer* health effects than exposure to a single chemical. Indeed, the opposite is much more likely, and additive or even synergistic effects can reasonably be anticipated.

3 Present and Proposed Regulatory Strategies Do Not Protect Public Health and the Environment

"If one were to spray purple paint all over the sidewalks and neighbors' fences, there would be a police action against you. Toxic chemicals are unseen but do more damage than paint and no one says a thing."[204]

— Steve Tvedten, Get Set Non-Toxic Pest Control

Most people made ill or whose property is contaminated or made unusable by others' pesticide use presently have less protection and recourse under the law than someone whose property is defaced with paint. In light of the illness, economic loss, and ecosystem disruption pesticide drift causes, major changes must be made to protect public health and the environment.

Spray drift that occurs during pesticide applications is poorly regulated by current state and federal laws and regulations. Post-application drift is barely regulated at all and is not acknowledged by U.S. EPA as an issue except for fumigant pesticides. Even then, risk mitigation measures exist only for a single fumigant, 1,3-dichloropropene, as it is the only one that has recently been re-registered. Inadequate enforcement capacity compounds the problem making it easy for pesticide applicators to flout laws with little threat of punishment.

Both U.S. EPA and DPR have authority to regulate drift, with U.S. EPA policies setting the regulatory "floor" for states. States are authorized to create more stringent regulations if they wish. California has done so with respect to drift, and is somewhat ahead of most other states in this regard. However, the analysis presented in this report shows that neither California nor federal policies prevent acute poisonings and sub-chronic and chronic exposures that exceed levels of concern. This chapter examines U.S. EPA and DPR failures in regulating drift.

Regulatory definition of drift ignores 80–95% of total drift for volatile pesticides

The most obvious flaw in both U.S. EPA and DPR regulatory processes for drift control is failure to define drift to include *all* forms of drift. U.S. EPA and DPR currently define drift as the airborne, off-site movement of pesticides that occurs during and immediately after application.[205] Yet our detailed analysis of monitoring data shows that, for volatile pesticides, the bulk of off-site movement occurs as they volatilize after application (see Figure 3-1). Such post-application drift usually peaks between 8 and 24 hours after the start of application, and can persist for many days above levels of concern (see Chapter 2). ARB monitoring data show that, for most volatile pesticides, post-application drift typically accounts for 80–95% of the total off-site, airborne movement of pesticides. Approximately 45% (84 million pounds in 2000) of reported pesticide use in California falls into the category of volatile pesticides.[206]

The most obvious flaw in both U.S. EPA and DPR regulatory processes for drift control is failure to define drift to include *all* forms of drift.

Data presented in this report make it clear that while controls at the time of application are *necessary* to reduce application-related spray drift, such measures are not *sufficient* to control post-application drift of volatile pesticides. To adequately address the full range of adverse effects caused by pesticide drift, post-application drift must be regulated as well as spray drift. The most effective approach would be to phase out or reduce use of the most dangerous drift-prone pesticides.

Spray-drift controls are ineffective

U.S. EPA label restrictions do not solve the problem

U.S. EPA has baseline responsibility for regulating spray drift through requirements written on the pesticide label. At present, labels may present one or more broad statements such as "Do not allow pesticide to drift," "Do not allow pesticide to contaminate persons not involved in the application," or "Do not apply pesticide when environmental conditions favor drift." A growing number of labels also specify allowable application equipment, spray droplet size, and weather conditions for application, such as "Do not apply when wind speeds exceed 10

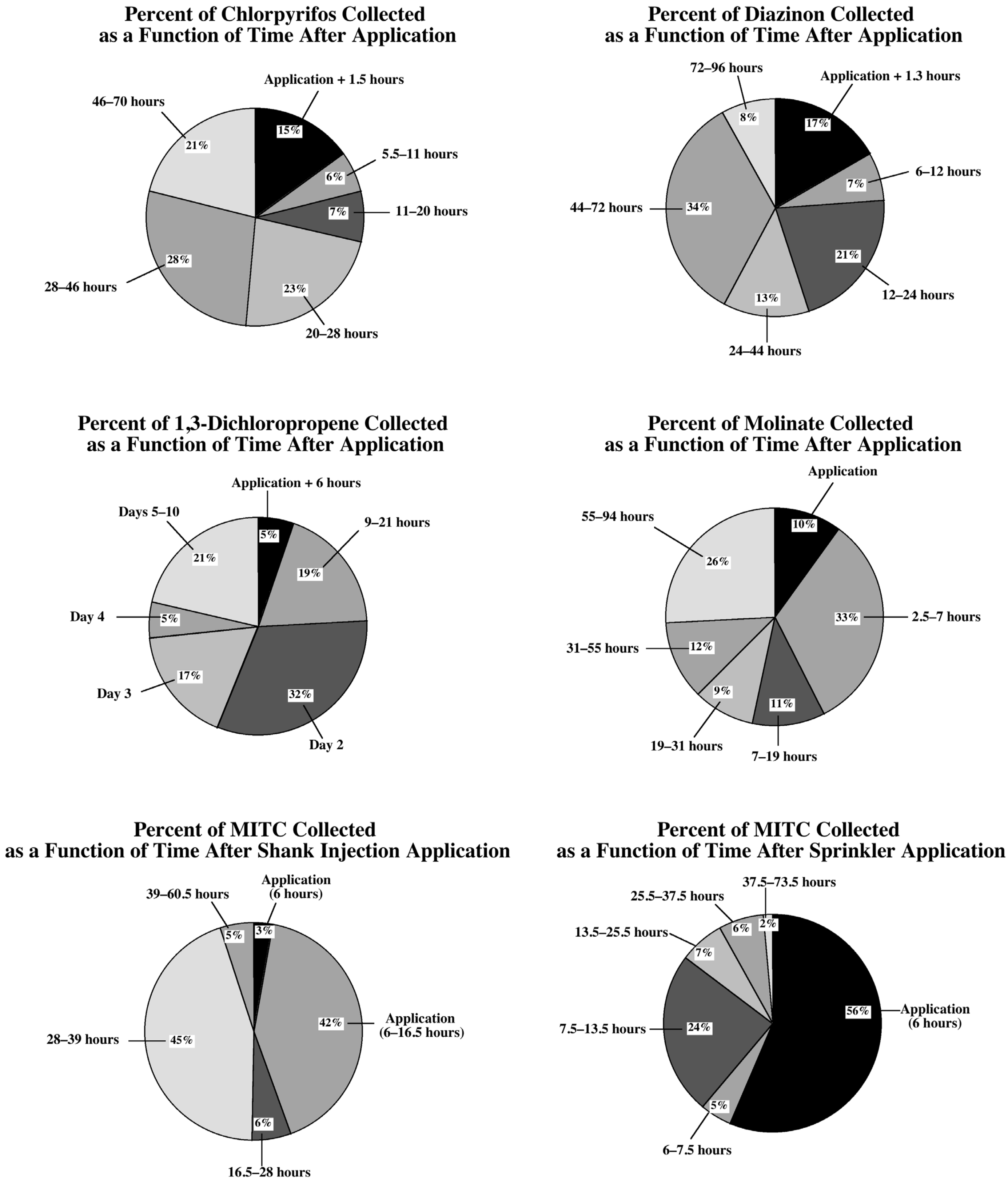


Figure 3-1
Most drift from applications of volatile pesticides occurs after application is complete, with typically only 5–20% of drift occurring during and immediately after application. MITC is an exception, with most drift occuring during the application period. See Appendix 3 for data, calculations and references for each pesticide.

mph." Many labels have no statement prohibiting drift, other than the worker protection statement that prohibits drift from contacting workers. Interestingly, labels on the most drift-prone pesticides—fumigants—carry none of these prohibitions. The only fumigant with any U.S. EPA-mandated drift mitigation measures on the label is 1,3-dichloropropene, which requires a 100–300 foot buffer zone.

The experiences of many whose yards, homes, cars, pets, livestock, and even themselves have been contaminated indicate continuing, serious problems with spray drift.

Even when label language specifies "no drift," the reality is quite different. Information presented in this report and the experiences of many whose yards, homes, cars, pets, livestock, and even themselves have been contaminated indicate continuing, serious problems with spray drift.

In 2000, U.S. EPA began the process of making labels more consistent across all products and solicited public comment on a proposal to revamp spray-drift label language.[205b] The stated intent was to develop

> "… improved and more consistent product label statements for controlling pesticide drift in order to be protective of human health and the environment."

Proposed changes would have required more detailed drift prevention directions on labels for all liquid or dust pesticides to limit movement of pesticide droplets and particles during and immediately after application. U.S. EPA proposed label language took a health-protective approach in stating that drift from an application site must not contact people; structures people occupy and associated property; parks, recreation areas, non-target crops, aquatic and wetland areas, woodlands, pastures, rangelands, or animals. Unfortunately the proposed label regulatory language introduced gaping ambiguity by allowing that some *de minimus* or low level of spray drift was inevitable, yet failing to specify what that excusable level was.

Industry opposition to U.S. EPA no-drift policy blocks implementation of proposed label controls on drift

Despite the limited scope of U.S. EPA proposed label language, pesticide applicators, growers, and pesticide manufacturers oppose it. Applicators argue that they cannot do their jobs unless they are allowed to contaminate other people's property, non-target animals, and/or water bodies. Growers, applicators, and industry representatives are lobbying for language that would only prohibit drift that causes "unreasonable adverse effects,"[207] leaving one to wonder what, exactly, constitutes a reasonable adverse effect. A label statement strongly favored by industry is:

> "Do not apply this product in a manner that allows spray to drift from the target application site and that may cause adverse effects at non-target sites."

This label statement would require that victims of drift prove not only that pesticides drifted onto their homes or yards, but also that the drift had caused adverse effects. The fact of chemical trespass would not be enough to trigger a violation. One problem with this is that adverse effects do not always occur immediately. For example, if drift contaminated someone's back yard, adverse effects might not appear until their children or pets played in the yard the next week and were affected, at which point it would be difficult to correlate spray drift with the illness. This approach to regulating spray drift would clearly fail to protect human health and the environment. To the contrary, it would simply legalize chemical trespass and make it convenient for applicators to be less careful in their work.

To its credit, the state of California objected to this weakened proposed language. DPR sent written comments to U.S. EPA asking that the statement be made more protective and enforceable by changing it to: "Do not apply this product in a manner that allows spray to drift from the target application site OR that may cause adverse effects at non-target sites."[208] This simple change of wording from "and" to "or" would uphold U.S. EPA "no drift" policy and extend it to all pesticides applied as sprays or dusts. Regional EPA offices around the country objected as well because removal of the zero-drift standard would make it even more difficult for those charged with enforcement to do their jobs.

As of April 2003, U.S. EPA has not made a final decision on the label language it will use. If the agency is serious about protecting human health, it *must* prohibit any chemical trespass and empower those who enforce the laws to prevent drift and prosecute violators.

California spray drift regulations are ambiguous and difficult to enforce

California laws and regulations on spray drift are somewhat more extensive than U.S. EPA baseline requirements, but still lack the clarity essential for effective enforcement. As a supplement to federal label requirements, California law specifies that pesticides be applied in a manner that prevents "substantial drift."[209] Substantial drift is defined in the regulations as "the quantity of pesticide outside of the area treated is greater than that which would have resulted had the applicator used due care."[210] "Due care" is not explicitly defined, but regulations specify[211] that no pesticide application shall be made or continued if there is reasonable possibility of:

- Any contamination of people not involved in the application process; or
- Damage to non-target crops, animals, or other public or private property; or
- Contamination of non-target property, including creation of a health hazard preventing normal use of such property. In determining a health hazard, the amount and toxicity of the pesticide, the type and uses of the property, and related factors shall be considered.

The law also states that "No person shall directly discharge a pesticide onto a property without the consent of the owner or operator of the property."

For a few specific herbicides and cotton defoliants, current California regulations specify spray-drift control measures intended to prevent damage to non-target crops, including minimum and maximum wind speeds during application, allowable application equipment, and buffer zones.[212] New methyl bromide soil fumigation regulations include buffer zones[155] and restrictions on when it can be applied close to schools.[213] The state has issued recommended permit conditions for other soil fumigants as well (see page 49), which counties may enforce at their discretion. Some counties impose additional permit conditions for pesticide use near schools, residential areas, or other sensitive sites (see Table 3-1). However, these conditions typically apply only to restricted use pesticides, a small subset of the total amount of pesticides used.

California s existing drift control measures apply only to restricted use pesticides, a small subset of the total amount of pesticides used.

U.S. EPA and DPR proposals for change are too limited in scope

Just as U.S. EPA is proposing changes to the pesticide label to control spray drift, DPR is proposing new drift regulations that would apply to all liquid pesticides that are sprayed, not just to the few now mentioned in the regulations.[214] This is a step in the right direction. Unfortunately, soil fumigants (34 million pounds in 2000 and 60% of the total pounds of Bad Actor pesticides used in California) and dusts (at least 60 million pounds of pesticides applied annually) are not addressed by DPR's preliminary proposed regulations. DPR's full proposal for regulating spray drift is on hold, pending finalization of U.S. EPA label language.

Both U.S. EPA and DPR approaches to drift control focus on details such as spray droplet size, minimum and maximum allowable wind speeds, and other technical specifications, most of which would be extremely difficult to enforce. Even if such conditions could be enforced, real-world experience

Table 3-1: Examples of County-Specific Conditions for Use of Pesticides near Schools, Residential Areas, and Field Crews

County	Buffer Zone or Other Site-Specific Condition
Contra Costa	Aerial applications of restricted pesticides are prohibited within 500 feet of school property and aerial applications of non-restricted pesticides are permitted only on weekends, holidays, or other times when there is no evidence of persons on school property. Ground applications of restricted materials within 500 feet of school property must be made during weekends, holidays, or other times when there is no evidence of persons on school property.
Fresno	Restricted use pesticides that have restricted entry intervals of 48 hours or longer cannot be applied within 1/8 mile of a school when the school is in session or an event is in process at the school.
Kern	Aerial applications of restricted pesticides are prohibited within 1/4 mile of residential areas, occupied labor camps, or schools in session.
Riverside	No agricultural pesticide applications shall take place within 300 feet of fieldworkers.
Santa Cruz	No application of any restricted pesticides is allowed within 200 feet of a school or child-care center during or one hour before or after stated business hours. Growers should contact school officials whenever a pesticide application is scheduled near a school.
Yolo	Aerial application of restricted pesticides within one mile of residential areas is not allowed unless the air movement is 90–180 degrees away from residential areas. Ground applications of agricultural pesticides labeled "Danger" are prohibited within 100 feet of sensitive areas and ground applications of agricultural pesticides labeled "Warning" or "Caution" are prohibited within 50 feet of sensitive areas. Sensitive areas include residences, schools, and bus stops.

Source: Personal communications with County Agricultural Commissioner staff for each county.

demonstrates that applicators may lack access to, or appropriate training in the use of, the latest technology. The fact that acute poisonings still occur with disturbing regularity suggests that such minor technology enhancements are simply not sufficient to solve the problem. Sub-acute or chronic poisonings from spray drift are likely to be even more common, yet label language does not address these exposures at all. Finally, the proposed technological controls in no way address the fundamental problems caused by intensive use of highly volatile pesticides. For this reason, technical specifications will not in the least mitigate post-application drift.

Proposed technological controls in no way address the fundamental problems caused by intensive use of highly volatile pesticides.

Enforcement against drift is weak and ineffective

Although a good written document that clearly states the law is the first step in creating effective regulation, the document is only as good as the enforcement behind it. U.S. EPA delegates all enforcement responsibilities to the states. In California, County Agricultural Commissioners (CACs) enforce pesticide label requirements and state regulations, with programmatic support and oversight from DPR. A state law passed in 2002, in response to Ventura County drift incidents that poisoned schoolchildren, expanded CAC authority to control pesticide applications near schools and raised the ceiling on fines for violations and non-compliance.[215] CAC staff respond to drift emergencies, investigate drift incidents, and have some control over the timing and conditions under which certain restricted use pesticides are used.

In practice, many drift investigations fail to prove violations. Counties are not well equipped to collect volatilized pesticides or gas samples, and air concentrations change rapidly. Samples must be collected quickly, before evidence degrades or drifts away. Residue testing methods are not available for all pesticides, and while the presence of residues definitively establishes drift, its absence does *not* prove drift has *not* occurred. Volatilized pesticides do not necessarily leave residues, which casts doubt on the wisdom of relying exclusively on surface tests for residues to determine whether drift has occurred. Exposure and poisoning can still occur via inhalation of invisible and often odorless, but still quite toxic, gas-phase pesticides moving through fields where workers labor and yards where children play.

Volatilized pesticides do not necessarily leave residues, which casts doubt on the wisdom of relying exclusively on surface tests for residues to determine whether drift has occurred.

Also of concern is that determination of reasonable possibility of contamination and of the amount of pesticide residue that constitutes a health hazard is highly subjective. County and state investigators are supposed to use statements of both the pesticide applicator and victims as supporting evidence. However, in some cases victims report that their sides of the story have not been solicited, and that when their statements conflict with those of the applicators, applicators are often given the benefit of the doubt.[216]

DPR recently issued a Pesticide Drift Incident Response Policy to CACs, which specifies that drift complaints should be investigated promptly, including anonymous and unwritten complaints.[217] However, the definition of drift DPR sets forth in this policy document mimics the federal definition, in that it does not include post-application drift. The state thus limits CAC responsibilities to spray drift only and discourages full protection of drift victims.

Finally, for many California counties, the most substantial barrier to enforcement is lack of resources. Even though California has a $25 billion agricultural sector and a sizeable pesticide enforcement branch, staffing is insufficient to ensure enforcement of regulations intended to prevent drift. For example, on July 29, 2000, 644 aerial applications were made in Fresno County alone, as well as the numerous ground and urban applications.[2b] The average daily number of only aerial applications in July 2000 in Fresno County was 362. This overwhelming number of pesticide applications makes it impossible for the 25 (29 during peak spray season)[218] enforcement staff in the Fresno County Agricultural Commissioner's office to monitor compliance with label instructions effectively. Adding to the problem of inadequate resources for monitoring of applicator performance, violations rarely elicit a substantial fine, or indeed, any fine at all, providing applicators little disincentive for ignoring the laws.[8]

Common-sense safety measures are not part of the plan

Except for a few pesticides, specific safeguards such as use of buffer zones and neighbor notification are not employed to mitigate human exposure. Federal Worker Protection Standards prohibit contaminating workers not involved in an application but do not specify any buffer zones around fields where workers are present. Interestingly, label-required buffer zones are used much more frequently to protect ecosystems and waterways than to protect humans.

Another obvious safety measure would be to require the applicator to notify people living or working on adjacent properties, but this is not even being discussed, much less seriously considered as a mandatory measure.

Post-application drift controls are almost non-existent

U.S. EPA does not regulate most post-application drift

U.S. EPA presently exerts little regulatory authority over post-application volatilization drift for non-fumigant pesticides, and has barely begun to acknowledge that this pathway can significantly contribute to total exposure. For fumigant pesticides, label restrictions—a buffer zone—exist only for 1,3-dichloropropene. U.S. EPA currently has no label restrictions targeting post-application drift for methyl bromide and MITC-generating pesticides.

U.S. EPA could exploit several avenues to regulate post-application drift. One opportunity arises during the registration process required by the Food Quality Protection Act (FQPA). The law explicitly states that U.S. EPA must consider aggregate exposure to a chemical and that any tolerances deemed "safe" for children must meet the definition Section 408 of the act prescribes, as follows:

> "DETERMINATION OF SAFETY—As used in this section, the term 'safe' with respect to a tolerance for a pesticide chemical residue, means that the Administrator has determined that there is a reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures *and all other exposures for which there is reliable information.*" (italics added)

In most risk assessments conducted to date, U.S. EPA has ignored airborne exposures from post-application drift, routinely dismissing them as unimportant without even evaluating California's extensive set of air monitoring data that demonstrates the scope of the problem.[219] Were they to take this step, they would find that inhalation exposures often dwarf the food and water exposures they spend so much time and effort evaluating, particularly for people living in or near agricultural areas. A case in point is molinate, where measured seasonal ambient inhalation exposures exceeded U.S. EPA-estimated dietary exposures for infants by a factor of 22 to 36, depending on location.[140]

Inhalation exposures often dwarf the food and water exposures U.S. EPA spends so much time and effort evaluating, particularly for people living in or near agricultural areas.

U.S. EPA could also use the Federal Clean Air Act, which specifically targets hazardous air pollutants (HAPs), to regulate pesticide drift.[220] Historically, regulatory activity around pesticides has focused only on releases of airborne pesticides from manufacturing facilities.[221] Because toxic releases from individual farm fields or other pesticide application sites do not exceed the minimum threshold for regulation as "major sources" and they have not yet been targeted as "area sources," existing regulations do not apply. Viewed collectively, however, pesticide emissions from application sites account for far greater toxic releases to air than emissions from pesticide manufacturing facilities, and should be regulated as area sources.

California Department of Pesticide Regulation does not enforce the Toxic Air Contaminant Act

In 1983, the California legislature passed the Toxic Air Contaminant (TAC) Act to protect public health from toxic airborne pollutants, including pesticides.[222] This law, properly implemented and enforced, could do a tremendous amount to reduce toxic post-application drift.

TAC law requires DPR to 1) prioritize a list of pesticides as candidates for TAC status, 2) estimate the potential for exposures by working with the California Air Resources Board (ARB) to conduct air monitoring, 3) evaluate the health effects of these chemicals in air, and 4) reduce exposures to such chemicals to levels "at which no significant adverse health effects are anticipated." The law established an external Scientific Review Panel (SRP) and requires DPR to submit all documents assessing exposures and health effects to the SRP for peer review.[223] The law also provides for public review and comment on TAC assessments.

Pesticides that fit the TAC definition—an air pollutant "which may cause or contribute to an increase in mortality or an increase in serious illness, or which may pose a present or potential hazard to human health"—must be listed as TAC chemicals.[224] DPR is then required to determine the extent and type of control measures needed to reduce emissions and protect the public.[225] Federally designated HAPs are automatically listed as TACs under the law.

Since the initial mandatory listing of 41 pesticides as HAP-TACs, the TAC process has moved at snail's pace for pesticides. Over the past 19 years, ARB and OEHHA have listed over 200 chemicals as TACs.[222b-c] During the same period, DPR listed only four pesticides—ethyl parathion, methyl parathion, tribufos (DEF), and MITC (including MITC-generating compounds such as metam sodium or dazomet). Draft TAC evaluations exist for three other pesticides—the insecticides chlorpyrifos and azinphos-methyl and the rice herbicide molinate—but reports have not yet been finalized. And although DPR has designated approximately 200 pesticides as "Candidate" TACs, it has failed to create an adequate prioritization scheme to ensure that the most drift-prone and hazardous chemicals be evaluated first.

The final step in the TAC process requires DPR to reduce risk of exposure to TACs. To date, only one TAC pesticide (ethyl parathion) has been cancelled, an action prompted mainly by the high risk of worker poisoning. DPR has instituted no new restrictions for tribufos (a cotton defoliant) and methyl parathion (an insecticide). For the most recently listed TACs, MITC and MITC-generating compounds, DPR stated that it plans to regulate only exposures that cause acute symptoms of poisoning and will not take into account the health effects of longer-term and/or lower level exposures, thus ensuring its actions will fall short of adequately protecting public and worker health (see page 50).[226]

Of the 41 HAP-TACs registered for use in California, DPR has begun the process of increasing restrictions for only a single pesticide—methyl bromide—and then only because the agency has been repeatedly sued for inaction and for promulgating inadequate regulations (see page 49). For another major-use HAP-TAC pesticide, 1,3-dichloropropene, DPR has changed conditions of use to allow more use with fewer restrictions since 1995, instead of imposing greater restrictions on use (see page 51).

This unilateral reorganization of the DPR risk assessment process fails to prioritize pesticides based on their toxicity and potential to be emitted to the air and severely compromises the public's right to know how decisions are made.

In November 2002, DPR retreated from its already minimal participation in the TAC process, declaring it would meet all DPR risk assessment mandates by developing a single process to assess risks across a variety of exposure routes including diet, drinking water, and air.[227] This unilateral reorganization of the DPR risk assessment process fails to prioritize pesticides based on their toxicity and potential to be emitted to the air and severely compromises the public's right to know how decisions are made, and to be involved in the process. It also blatantly flouts state law by eliminating the oversight of the SRP, which has worked hard to ensure that DPR bases regulatory decisions on scientific principles rather than politics. DPR decisions on which pesticides it will consider for listing as TACs will now be made without peer review of the scientific validity of their prioritization scheme or the science used to evaluate risk and exposure assessments. A review of past SRP judgements on the quality of DPR work in these areas does not inspire confidence in DPR.[228]

As an example of the kinds of decisions DPR makes beyond the light of peer-review and public scrutiny, consider the handling of two of the three pesticides now in the queue to be evaluated as potential TACs. When DPR unilaterally excused itself from the TAC process, it decided, independently of the SRP and without soliciting public comment, that airborne exposures to these three pesticides—chlorpyrifos, molinate, and azinphos-methyl—did not exceed levels of concern. It then removed draft reports on these pesticides from the DPR website. However, for chlorpyrifos, analysis of near-field exposures presented in this report (see page 34) shows that peak concentrations exceeded the acute REL for adults by a factor of eight and that for a one-year-old child by a factor of 184. Independent analysis of ambient (regional) exposures by other researchers estimated that concentrations of chlorpyrifos in ambient air exceeded the acute REL for 50% of children in the exposed population.[106] DPR rationale for not listing this pesticide as a TAC thus cannot be scientifically based.

Similarly, our analysis for molinate (see page 38), which uses RELs from the U.S. EPA 2002 preliminary risk assessment, found that near-field acute exposures were approximately equal to the adult acute REL and exceeded the one-year-old child acute REL by a factor of 22. Sub-chronic concentrations of molinate in ambient air exceeded RELs by a factor of 2.8–5.6 for children living in towns near rice-growing areas. DPR concluded that molinate exposures do not pose significant health concerns, yet did not use the most recent U.S. EPA risk assessment data available or include an extra uncertainty factor for protecting children's health, as the uncertainty in the data demand.[229]

In light of DPR's historical systematic bias *against* taking steps that would protect public health, it is hard to have confidence that decisions it makes behind closed doors and out of the light of public scrutiny and peer review will sufficiently protect human health.

DPR stalls effective regulation of the most drift-prone fumigant pesticides

As data in Chapter 2 indicate, fumigant pesticides are particularly problematic because of their high use, high toxicity, and extreme volatility. In this section, we present California regulatory issues surrounding these chemicals. The common thread connecting these accounts is the willingness of DPR and pesticide manufacturers to cut corners and gamble with worker and public health to preserve access to these highly toxic, hard-to-control fumigant pesticides. As detailed below, DPR has stalled repeatedly in implementing use limits, buffer zones, and other protections against fumigant drift.

DPR fails to reduce sub-chronic exposures to methyl bromide

Faced with toxicity data linking low-level methyl bromide exposure with potential to cause birth defects and adverse neurobehavioral effects, DPR began working with the methyl bromide industry in the early 1990s to modify application methods and recommend buffer zones. Counties were left to enforce the measures through pesticide permit conditions (see Appendix 4). Community members and environmental and farmworker advocacy organizations repeatedly expressed concern about the pesticide's health effects and about the legality of relying on permit conditions—which are not subject to public comment and are issued at the discretion of the CAC—to regulate methyl bromide use.

In 1999, a group of public interest organizations filed suit and prevailed, forcing DPR to develop uniform statewide regulations governing methyl bromide field fumigation.[230] However, the resulting regulations, which took effect early in 2001, failed to address the health hazards of sub-chronic exposure to methyl bromide, as well as concerns about the adequacy of buffer zones. DPR's recently finalized risk assessment for methyl bromide concludes that exposure levels can sometimes be expected to exceed even the acute REL at current buffer zones, particularly around large fields (more than 30 acres) under fumigation.[231]

With 2000 monitoring data showing that seasonal ambient methyl bromide concentrations exceeded sub-chronic RELs (see page 27), DPR had a sound scientific basis for severely restricting use of this highly toxic fumigant. The state initially pledged to have additional controls in place by summer 2001. It had concluded that the best option for keeping exposures below the sub-chronic REL was to limit applications to no more than 20,000 pounds in any given township (a 36-square-mile area) in a single month.[232] But in June 2001 DPR abruptly reversed course. It claimed that limiting monthly use was unworkable and that it would wait and see whether new regulations (adopted early in 2001) would be effective in reducing air levels of methyl bromide.[233] However, since the new regulations were only intended to prevent acute health effects of short-term exposures, it was highly doubtful that this approach would adequately protect human health from the effects of sub-chronic exposure. Indeed, ambient monitoring conducted in 2001 showed that methyl bromide levels again exceeded the sub-chronic REL in several locations, proving the new regulations were not effectively reducing sub-chronic exposures.

New 2001 regulations failed to address the health hazards of sub-chronic exposure to methyl bromide.

A new round of emergency methyl bromide regulations issued in September 2002 still failed to address sub-chronic exposure,[234] meaning another fall fumigation season passed without meaningful protection

CRLA Sues Over Methyl Bromide Use Near Schools on Behalf of a Monterey County Resident

Strawberry and vegetable fields treated with large quantities of methyl bromide surround a number of Monterey County schools. Measured levels of methyl bromide in air over a seven-week period at two of these schools (La Joya Elementary and Pajaro Middle School) in 2000 exceeded the DPR sub-chronic REL for children. A concerned neighborhood resident decided to take action to block further methyl bromide use adjacent to schools (Carillo v. DPR). California Rural Legal Assistance Inc. sued for greater use restrictions around affected schools.[236] Monterey County Superior Court granted a Temporary Restraining Order directing both the county and state to ensure the target REL was not exceeded. The lawsuit was subsequently settled, with the condition that DPR increase buffer zones and use restrictions around the schools in question and consider sub-chronic exposures when it re-issued methyl bromide regulations.

for residents in high methyl bromide use regions. As a result of the court settlement in Carillo v. DPR and Monterey County Agricultural Commissioner (see page 49), DPR agreed to consider regulation of sub-chronic exposure. In February 2003, DPR announced its intent to do so, with a plan to propose new regulations by mid-May 2003.[235]

In its latest attempt to avoid the obligation to reduce sub-chronic methyl bromide exposures, DPR is now attempting to relax the sub-chronic REL for methyl bromide. A February 2003 addendum to the risk assessment proposes to increase the sub-chronic REL from 1 ppb to 9 ppb for children and from 2 ppb to 16 ppb for adults.[237] To calculate this revised REL, DPR utilized a new industry-sponsored toxicology study carried out under conditions that leave serious questions about the validity of the results. At least one DPR scientist concluded that results support the current RELs (1 ppb and 2 ppb), and OEHHA has taken the position that the REL should remain at 1 ppb "due to the overall poor quality of the data and uncertainty in protection of infants and children, and the uncertainty in the evaluation of methyl bromide/chloropicrin formulations".[238] OEHHA concluded there was no scientific justification for giving the results of the new study more weight than the prior study which was used to set the 1 ppb REL. The controversy remains unresolved as this report goes to press.

Adequate protection from MITC drift is still in the future

DPR issued an August 2002 memo stating its intent to list metam sodium and several other MITC-generating chemicals as toxic air contaminants.[239] The final MITC TAC report concluded that MITC levels in air routinely exceed both acute and sub-chronic RELs under currently permissible use conditions.[132] That December, DPR published a risk management directive indicating that use restrictions will be developed to reduce acute exposures of residents and bystanders only to the no observed effect level, the point where no eye irritation has been observed in adult volunteers.[226] No added margin of safety will be required for children, asthma sufferers, or other sensitive individuals. DPR states that it is delaying any action to reduce worker exposure until a full risk assessment is complete, even though the TAC report demonstrates that bystanders, including fieldworkers laboring near metam sodium application sites, will suffer excessive MITC exposure. Lastly, DPR states that it will take no action to mitigate seasonal (sub-chronic) exposures until after a policy for reducing acute exposures has been implemented, delaying important decisions needed to reduce health impacts of sub-chronic MITC exposure.

Buffer zones are one of the major protections DPR could implement to lessen the effects of MITC drift. At present, no statewide regulations require the use of a buffer zone for metam sodium applications. DPR recommends, but does not require, minimum 500-foot buffer zones between sprinkler and shank applications and occupied structures, with local permit conditions determined by CACs.[240] Due to a May 1999 drift incident in Cuyama (see Table 2-4 on page 30), both Santa Barbara[241] and San Luis Obispo[242] counties prudently began to require one-mile buffer zones between metam sodium sprinkler applications and occupied structures. At the time of the Earlimart poisoning incident (see page 15), Tulare County required a buffer zone of only 500 feet between sprinkler applications of this fumigant and occupied structures. According to a DPR report, twenty residents out of a total of 173 reporting symptoms lived more than eight tenths of a mile from the fumigation.[170] Since the incident, Tulare County and several other Central Valley counties have changed permit conditions for metam sodium sprinkler applications to require a one-half mile buffer zone between sprinkler applications and occupied structures.[243] For soil injection applications, a 500-foot buffer zone still applies, but evidence from the Arvin poisoning incident (see page 29) indicates that this buffer is inadequate, since all those affected were 513 feet or more from the fumigated field.

Buffer zones are one of the major protections DPR could implement to lessen the effects of MITC drift.

Current buffer zones target residents in occupied structures but exclude farmworkers and other outdoor workers from protection. For example, Kern County enforces a half-mile buffer zone between metam sodium sprinkler applications and residences, but no buffer zone is required to protect field crews. Based on the Cuyama incident, the California Department of Health Services (DHS) now recommends a minimum one-mile worker buffer zone for all metam sodium sprinkler applications for at least 72 hours.[244] Yet even with this recommendation, DPR's recent MITC Risk Management Directive indicates that it will continue to ignore worker exposures for the foreseeable future.

One reason that metam sodium applications all too often result in illness from off-site drift is that current rules rely on using odor to monitor drift. DPR guidelines specify that workers must monitor application sites for odor during and after the application and apply more water if odor is detected. This is both hazardous for workers and an unreliable method for early drift detection, because the main metam sodium breakdown product, MITC, causes eye irritation at levels below the odor threshold. The Occupational Health Branch of California DHS has recommended that DPR reassess this requirement.[244]

DPR accommodates Dow and allows expanded use of carcinogenic fumigant 1,3-dichloropropene

In 1988, 16 million pounds of 1,3-dichloropropene (Telone) were reported used in California, making it the second most heavily used pesticide that year (see Figure 2-1, page 24). In 1990, ARB monitoring found alarmingly high air levels of this cancer-causing fumigant in Merced County. The estimated lifetime cancer risk from exposure at average levels measured in air was 92 in one million, far in excess of the "acceptable" cancer risk of less than one in one million. ARB alerted the California Department of Food and Agriculture (CDFA)[245] and Telone use was suspended,[246] with the understanding that CDFA would work with the manufacturer, Dow Chemical Company, to develop lower-emission application techniques.

In 1995, Telone was reintroduced on a limited basis in 13 counties, with use in any field limited to only once every three years. Statewide use that year was 410,000 pounds. ARB conducted air monitoring in the two highest-use counties, Merced and Kern, in both 1995 and 1996. Recent analysis by scientists outside of DPR estimates that cancer risk was still elevated at even this level of use, at two in one million additional cancer cases for 25% of the exposed population and ten in one million for the 5% of the population most heavily exposed.[106] Yet in 1996, DPR dramatically relaxed Telone use restrictions, permitting use in all counties, every year, on any given field. Use in any township (a 36-square-mile area) was capped at 90,250 pounds per year. Curiously, a DPR risk assessment for Telone finalized in 1997 states on the first page that it applies only to the more restrictive 1995 use conditions.[134]

In 1996, DPR dramatically relaxed Telone use restrictions, permitting use in all counties, every year, on any given field and, in 2001, DPR quietly authorized Telone use above the 90,250 pound cap in 5 townships, without public notice.

By 2000, Telone use had increased sharply to 4.4 million pounds annually, and in 2001 DPR quietly authorized Telone use above the 90,250 pound cap in 5 townships (three in Merced and one each in Kern and Del Norte), without public notice or provision for public comment. The two air monitoring stations where the highest Telone levels were measured in 2001 in Arvin and Shafter (see Figure 2-5, page 32) are both in the Kern County township where increased use was allowed.[247]

In 2002, DPR announced an agreement with Dow that permits use of up to 180,500 pounds per year in any township (twice the current limit), as long as average annual use since 1995 remains below 90,250 pounds.[248] In essence, each township now has a Telone "use credit" to draw on for those years between 1995 and 2001 when township use was less than 90,250 pounds. This decision was made without public input or published evaluation of the cancer risk associated with concentrations measured in 2000 and 2001. With cancer risks already above the one in one million level before expanded Telone use, and dramatically increased cancer risks between 1996 and 2001, DPR is clearly falling far short of

History of 1,3-Dichloropropene Use Restrictions in California	
1990	ARB monitoring of Telone in air and CDFA suspension of use.
1990–1995	Telone manufacturer Dow modifies application methods.
1995	DPR permits limited reintroduction of Telone, with significant restrictions.
1996	Some restrictions lifted. Expanded use allowed.
1997	Risk assessment released which states that it only applies to 1995 use conditions.
2000, 2001	Air monitoring shows increasing Telone air concentrations.
2002	DPR relaxes Telone use caps statewide.

adequately safeguarding public health. Unfortunately, the impact of increased use in 2002 and 2003 will not be evaluated because DPR has scheduled no additional Telone air monitoring.

It is important to realize that estimated lifetime cancer risk levels will increase if use is allowed to increase, but could be much lower if 1,3-dichloropropene use is ended in the near future. DPR and U.S. EPA should heed these risk estimates as a warning of the need to end, not expand, use of this cancer-causing fumigant.

Replacing one fumigant with another does not reduce toxic air pollution

History shows that when regulatory action restricts use of one fumigant, use of other fumigants increases. Because methyl bromide is an ozone-depleting chemical, it is scheduled for phaseout in California in 2005 under the Montreal Protocol. While methyl bromide use has dropped over the last several years as a result of production cuts and the impending phaseout, use of other soil fumigants has risen (see Figure 2-1, page 24). The steady increase in Telone use is especially troubling because of the high cancer risk posed by this pesticide. Poised to add yet another drift-prone, cancer-causing chemical to the list of fumigants, U.S. EPA and DPR are now evaluating methyl iodide for registration as a soil fumigant (see page 33).

Reducing fumigant use is the best way to reduce exposure

Fumigant illness episodes, high fumigant air concentrations, and a growing body of toxicology studies have pushed DPR in recent years to explore ways to reduce fumigant drift. However, efforts have centered on modifying application methods (thicker tarps, deeper injection, applying more water) and creating buffer zones (some as narrow as 30 feet). Some of these changes, made without adequate testing of effectiveness, have in fact worsened exposure. For example, hot drip and bedded applications and very high barrier tarps actually contribute to increased methyl bromide drift.[249]

Limitations on use in a given geographic area over a specific time period are proven to reduce fumigant drift. Unfortunately, DPR has only set limits on yearly use per township for Telone, and these have been steadily eroded over time.

The best solution would be a program of research and implementation of less toxic methods of controlling soil-borne pests, with incentives to adopt these methods and disincentives for continued soil fumigant use. Existing alternatives include soil solarization with and without soil amendments, development of disease-resistant varieties, crop rotation, and biological control of soil pests.[250] Unfortunately, a systematic effort to reduce fumigant use and substitute less-toxic alternatives has yet to be developed.

A fundamentally different approach is necessary to solve the drift problem

This report presents data and analysis that should be a wake-up call to farmers, agency officials, and politicians that fundamental changes in pesticide use must be made to prevent toxic air pollution on such a grand scale. Minor fixes to existing regulatory controls will not solve this problem. A change of mindset and evaluation of the problem from a fundamentally different point of view are required.

U.S. EPA and DPR must begin with the most basic step—evaluate existing air monitoring data and acknowledge that secondhand exposures from all forms of drift pose a serious public health threat.

U.S. EPA and DPR must begin with the most basic step—evaluate existing air monitoring data and acknowledge that secondhand exposures from all forms of drift pose a serious public health threat. If these agencies continue to ignore the fact that drift occurs even when applicators follow label instructions, their claims that decisions are based on "sound science" are merely hot air.

Once this fact is acknowledged, concrete steps to prevent drift must be taken. The next chapter outlines a set of recommendations that would move us towards cleaner air and more sustainable farms.

4 Recommendations: Phase Out Problem Pesticides and Create Stronger Drift Controls

Pesticide drift creates a "lose-lose" situation for all involved, including residents of the agricultural-urban interface and rural communities, farmworkers, fish and wildlife, organic farmers, and even conventional farmers and pesticide manufacturers. It is time for U.S. EPA and California DPR to create real solutions that will truly protect human health and the environment from pesticide drift. Both agencies need to take an appropriately cautious approach to regulating drift, not just because of known adverse effects, but also because of the many *unknowns,* including the limited availability of air monitoring data, the paucity of toxicity data for inhalation exposures, and the unknown health effects of simultaneous and cumulative exposures to multiple pesticides and other airborne contaminants.

We call on U.S. EPA and DPR to phase out the most hazardous, drift-prone pesticides and pesticide application methods, and to create strong, effective, and enforceable drift laws and regulations. We recommend the following specific actions.

At both the state and federal levels

- **Phase out use of highly toxic, high-use fumigant pesticides.** California's recent monitoring data show serious exceedances of "acceptable" seasonal exposures to these highly toxic chemicals in ambient air. U.S. EPA must regulate these pesticides at a national level so growers from different states must all follow uniform laws. The most effective strategy for controlling fumigant drift is to eliminate use of these dangerous pesticides altogether. Absent a complete ban, large buffer zones and caps on amounts applied in a given time period in a particular area should be implemented as soon as possible.
- **Assist growers in the transition to less-toxic alternatives.** Implementation of state and federally supported efforts to help farmers and urban residents adopt more sustainable pest-control methods is essential to reduce pesticide use and corresponding drift. The U.S. Department of Agriculture and the California Department of Food and Agriculture must invest resources in research, development, and extension services that help growers move away from toxic pesticides. Organic farmers have successfully used alternatives to pesticides for years in California and elsewhere. In urban settings, efforts should be made to educate residents in least-toxic integrated pest management and prohibit toxic pesticide use.
- **Define pesticide drift to include all airborne, off-site movement of pesticides.** We propose the following drift definition: "The physical movement of pesticide droplets, particles, or gas-phase chemical away from the application site during and after the pesticide application. Drift includes spray droplets created during the application, gas-phase chemicals from fumigant applications or volatilization of applied pesticides, airborne dusts or powders, and pesticide-contaminated airborne soil particles."
- **Design drift controls that are effective in preventing drift from all sources.** Regulations and label statements should take into account the fact that humans make mistakes and do not always follow label instructions, equipment may be miscalibrated, and weather conditions (wind speed and direction, temperature, etc.) may change after pesticide application. This will almost certainly involve eliminating the use of some pesticides and application methods and requiring buffer zones for many applications. Drift controls should protect all people—especially those most sensitive (such as asthmatic children, pregnant women, and developing fetuses) or those disproportionately affected by pesticide use—as well as the most sensitive sites (including organic crops).
- **Design easily enforceable drift controls.** Those charged with enforcing drift laws and regulations need clear and unambiguous guidance to effectively assess whether a violation has occurred and the authority to levy substantial penalties on violators. To this end, U.S. EPA and DPR should:

  Require buffer zones for all spray and fumigant applications. To prevent exposures from spray drift and from post-application drift, U.S. EPA and DPR must require buffer zones (no-spray zones) as part of label restrictions for drift-prone pesticides and application methods. Neighboring communities and workers should not have to suffer any level of chemical trespass onto their homes, property, businesses, schools, and workplaces, just so others have maximum convenience and flexibility in the use of pesticides. A regulatory construct compatible with the drift definition proposed above would be to require substantial buffer zones (at least 300 feet) for applications of pesticide products containing volatile active ingredients or hazardous "inerts" with a vapor pressure greater than 10^{-7} mm Hg at 25°C.

Buffer zones must lie within the property on which the pesticide is applied and be clearly defined so they do not include public lands, public thoroughfares, or adjacent private properties (unless explicit written permission of the property owner has been granted). Under no circumstances should buffer zones be permitted to include occupied dwellings or recreation areas. Buffer zones also must be large enough to protect workers in adjacent fields, neighboring organic farms, and all housing, schools, and workplaces within a specified radius of the application. Buffer zones should be delineated for all possible weather scenarios, such as inversions or changes in wind speed and direction.

Require posting and notification of pesticide applications. U.S. EPA and DPR should rewrite regulations and pesticide labels to require 24-hour advance written notification of all residents and property owners within 1/4 mile of any pesticide use that has the potential to drift off-site at any time during or after application. Information should be provided in both English and Spanish and include anticipated date and time of application, contact information for both the property owner and the applicator, the name of the pesticide product, a list of active ingredients and other "inert" ingredients, and credible information on both acute and chronic toxicity of the product(s) being applied.

Ban use of spray technologies that facilitate drift. Aerial spraying is particularly problematic. U.S. EPA and DPR must quickly phase out drift-prone technologies and replace them with less hazardous, more ecologically sophisticated alternative pest-control methods.

Allow applications only within a range of minimum and maximum wind speeds. This strategy is important for reducing spray drift during applications. Wind speeds between one and ten miles per hour are generally considered acceptable. High winds blow pesticides off the intended target, and no-wind conditions usually occur with temperature inversions, which trap spray droplets and pesticide vapors in an area close to the field. However, wind-speed controls do not address post-application drift, since post-application winds are unpredictable.

- **Consult with affected communities and regulate to protect them.** Pesticide drift adversely impacts many different communities, all of which deserve a place at the table when changes in regulatory strategies are negotiated. U.S. EPA and DPR must recognize that these groups do not have the resources that grower and pesticide manufacturing industries have to lobby them, and must therefore make additional efforts to ensure their inclusion. Regulatory controls should be designed to protect affected people, not just grower and industry profits.
- **Require pesticide manufacturers to fund air monitoring as a condition of continued registration.** The volatility of the active ingredient is a key factor affecting airborne off-site movement of pesticides. As a condition of continued registration of their products, manufacturers of pesticides with active ingredients or toxic "inerts" with a significant vapor pressure (>10^{-7} mm Hg at 25°C) should be required to fund ARB and DPR to conduct air monitoring.
- **Do not allow introduction of methyl iodide as a methyl bromide replacement.** Introducing yet another toxic fumigant will only exacerbate the drift problem, as it perpetuates grower dependence on chemical pest controls. U.S. EPA should deny this neurotoxic and carcinogenic substance registration in the U.S., and California should deny registration even if U.S. EPA fails to.

In California

- **Implement the Toxic Air Contaminant Act.** Governor Davis and the legislature must force DPR to resume its mandate to implement the Toxic Air Contaminant Act. The state must provide the necessary funding to do this important work, ideally through a "polluter pays" policy that makes pesticide users pay for the regulatory infrastructure required to deal with the associated adverse effects. In particular, the governor and legislature must require DPR to:

Implement use restrictions for MITC-generating pesticides that will reduce both acute and sub-chronic exposures for workers and residents of rural communities.

List chlorpyrifos and molinate as TACs and take immediate steps to reduce airborne exposures to them by severely restricting or eliminating use.

Implement substantial restrictions on use of TAC and HAP-TAC pesticides, starting with methyl bromide and 1,3-dichloropropene.

Accelerate evaluation of chemicals as potential TACs, prioritizing the fumigants chloropicrin and sulfuryl fluoride and the insecticide diazinon for immediate attention.

Make the risk assessment process and corresponding risk management decisions transparent.

- **Improve enforcement of existing regulations.** County Agricultural Commissioners should routinely levy the maximum allowable fines for drift violations to truly deter non-compliance. Penalty revenue should be used to establish a state fund for medical expenses of victims of drift incidents. Resources for spot monitoring of drift and for responding to drift incidents should be increased.
- **Establish and implement a uniform pesticide poisoning response protocol.** Pesticide drift poisons many people, but it is difficult for victims to report incidents because the process for doing so is often unclear and varies greatly from county to county. In conjunction with CACs, DPR must develop a standard, accessible statewide pesticide poisoning response protocol to inform, protect, and assist victims and punish violators.

At the federal level

- **Maintain a no-drift standard in pesticide label language.** U.S. EPA must use the pesticide label to send a clear message that pesticide drift from a target site in any amount is an illegal toxic trespass. The burden of proof cannot be placed on victims to prove that drift has caused adverse effects. The label must also provide legal recourse for those who cannot obtain enforcement actions through their state regulatory system. We recommend the following label language:

  > "Do not apply this product in a manner inconsistent with the Best Management Practices summarized below or that allows spray to drift from the target application site and contact people, regularly occupied structures and the associated property, parks and defined recreation areas, non-target crops, aquatic and wetland areas, woodlands, pastures, rangelands, livestock, pets, wildlife or other non-target sites. Do not apply this product in a manner that may cause risk of adverse effects to humans, animals, or other non-target sites."

- **Include airborne pesticide exposures in pesticide risk assessments for all pesticides.** U.S. EPA should use California and any other available air monitoring data to evaluate residential "bystander" and fieldworker exposures via both spray drift and post-application drift from agricultural applications for all pesticides. These results should be included in U.S. EPA risk assessments and used to make risk management decisions more protective of health.
- **Reduce allowable application rates.** U.S. EPA must require manufacturers to reduce recommended label application rates to lower the absolute amounts of pesticides released into the environment. Agricultural engineering research indicates that efficacy in pest control can be achieved with vastly lower application rates (50-80% of those presently prescribed)[251] with appropriate spray technologies. Combined with biologically based integrated pest management, this approach would save farmers money by reducing the amount of pesticides they use and result in significant progress towards reducing drift.
- **Issue new regulations under the Clean Air Act to classify pesticide application sites as "area sources" subject to regulation.** Regulations should cover farm fields, commodity fumigation chambers, sites of structural pesticide use, and any other sources of substantial pesticide releases to the air.

Appendix 1: Interpreting Human Health Studies

Epidemiology is the study of diseases and their causes in human populations. It compares groups or individuals with an exposure or disease with those without. For example, groups with cancer ("cases") are compared with groups without ("controls"). Or people with pesticide exposure (cases) are compared with those without (controls). Such studies might ask whether those with cancer (cases) are more likely to have exposure to pesticides than those without (controls). Or whether those with pesticide exposure (cases) are more likely to have cancer or other diseases than those without (controls).

How study results are reported

Study results are expressed as risk ratios. See below for ratios commonly used in epidemiologic studies. These ratios indicate whether people with cancer were more likely to be exposed to pesticides (at increased risk), equally likely (no association or no difference in risk), or less likely (at decreased risk) than those without cancer. Or whether those with pesticide exposure had increased risk of cancer, no difference in risk, or decreased risk relative to those without exposure.

For example, in a study of leukemia in children, the cases would be children with leukemia, and the controls children without it. The children with leukemia could be more likely, equally likely, or less likely to have exposure to pesticides.

1. **More likely:** A ratio greater than 1 (> 1) indicates children with leukemia were more likely to have exposure to pesticides—that pesticide exposure increased the risk of leukemia. The size of the ratio indicates how much the risk grew. A ratio of 1.4 means a 40% increase in risk. A ratio of 2.0 means doubled risk, or a 200% increase. Risks double and above are considered more important than ratios less than 2.
2. **Equally likely:** A ratio equal to one (= 1) means that children with or without leukemia were equally likely to have pesticide exposure—that there was no association with pesticides, neither increased nor lessened risk of leukemia.
3. **Less likely:** A ratio less than one (< 1) suggests that children with leukemia were less likely to have pesticide exposure than children without it—that risk declined. The smaller the number the lower the risk. A ratio of 0.80 means children with leukemia were 20% less likely to have been exposed to pesticides. A ratio of 0.40, that they were 60% less likely.

Other factors affecting disease outcomes

When studying humans, determining every factor that might influence outcomes is impossible. Observed increase in risk might come not from the pesticide in question, but something researchers dismiss or fail to consider. Or it could be from pesticide exposure combined with other unknown or unstudied factors, or occur by chance. Therefore, finding an increase in risk does not strictly mean that pesticides "cause" leukemia. Therefore, increased risk is commonly expressed by stating that "pesticide exposure increases the risk of leukemia in children" or that "pesticide exposure is a risk factor for leukemia in children," and not that pesticides "cause" leukemia.

Are study results "significant"?

Methods to determine how strong the associations between leukemia and pesticides are and whether they occur by chance are called tests of statistical significance. The statistical particulars are usually omitted and summarized as "significant" or "not significant" findings. The two most common tests are the "p" value and confidence intervals.

1. **"p" value:** This tests whether the findings could have occurred by chance 5% of the time or less. The 5% is converted to a fraction and written as 0.05. For example, results will appear as "p = 0.05" (read as p equal to point 0,5), or "p < 0.05" (p less than point 0,5), or "p ≤ 0.05" (p less than or equal to point 0,5). If the "p" value is less than or equal to 0.05, the findings are considered statistically significant; that is, they are unlikely to have occurred by chance. The smaller the "p" value the more significant the findings. For example "p ≤ 0.01" (p less than or equal to point 0,1) means it could occur by chance 1% of the time or less.
2. **Confidence intervals:** The confidence interval, another widely used test, shows how close the risk ratio found in the study is to the "true" or expected value. The level used is usually 95%. This means that were you to do the study repeatedly, 95% of the time the results would be within the calculated interval. Conversely, 5% of the time they would not.

   Because it is an interval, there are two numbers, the lower written first. If the lower number is less than or equal to one (≤ 1), the increase in risk is "not significant" or "non-significant." If it exceeds one (> 1), the increase in risk is "significant."

   When the number of cases is small, researchers are less confident that findings are valid for broader populations. This is expressed as a very wide confidence interval (a large difference between the lower and higher numbers). The larger the number of people in a study (sample size), the narrower the confidence interval and greater the significance attached to the findings.

Commonly Used Ratios and their Abbreviations

FR—Fecundability Ratio
OR—Odds Ratio
PMR—Proportionate Mortality Ratio
PCMR—Proportionate Cancer Mortality Ratio
PR—Prevalence Ratio
RR—Relative Risk (or Rate Ratio)
SMR—Standardized Mortality Ratio
SHR—Standardized Hospital Ratio
SMbR—Standardized Morbidity Ratio
SIR—Standardized Incidence Ratio
SPR—Standard Proportional Ratio
SRR—Standardized Rate Ratio

Appendix 2: Risk Assessment, Reference Exposure Levels (RELs), and Cancer Risk Calculations

Risk assessment

U.S. EPA and DPR use the process of risk assessment to determine how much exposure to a single pesticide is "acceptable" for both adults and children, the level believed to cause no adverse effects over a certain period of time. Risk assessment consists of the following steps:

- Determining the health effects caused by exposure to a particular pesticide, using laboratory animals and data from known human exposures where available.
- Assessing all possible routes of pesticide exposure, including food, drinking water, air, and skin contact. Evaluation of additional exposures for children requires examining specific child behaviors such as playing on the ground and mouthing objects, or pesticide use patterns that result in skin contact (head lice treatments or insect repellents, for example).
- Determining the relationship between the amount of exposure (the dose) and the extent of health effects to find the "no observed adverse effect level" (NOAEL) or the "no observed effect level" (NOEL) in laboratory animals. These values are derived from an animal (usually rats, but mice, dogs, and other mammals also) study which is representative of the level believed to cause no adverse effects over a selected time period using the most sensitive toxicity endpoint. Typically, a "critical study" is chosen that gives the lowest NOAEL (the most protective approach) for all of the possible toxic endpoints caused by the pesticide. Some toxicity studies do not produce a NOAEL (or NOEL). That is, the substance is toxic at all doses tested. If this is the case, the Lowest Observable Effect Level (LOEL) is used, along with an additional uncertainty factor.

Non-cancer toxicity of a substance in laboratory animals is typically assessed for acute, sub-chronic, and chronic exposures. In human terms, acute exposures are from one to 24 hours, sub-chronic exposures one month to several years, and chronic exposures eight years to a lifetime.[252] Carcinogenic effects are assessed assuming daily exposure over a 70-year lifetime.

Calculation of non-cancer Reference Exposure Levels (RELs)

In this report, we use the term Reference Exposure Level (REL) to mean the concentration of the pesticide in air at which no adverse effects are anticipated based on laboratory studies of exposure to a single chemical. Both acute and sub-chronic RELs were determined for both an adult male and a one-year-old child for the six pesticides this report examines. The process involves:

- Converting the animal NOAEL (or NOEL) into a concentration of the substance in air that is the "acceptable" level for the laboratory animals used in the test.
- Converting the "acceptable" concentration for laboratory animals into an "acceptable" concentration for humans (the REL) using uncertainty factors.

Conversion of No Observed Adverse Effect Levels (NOAELs) into air concentrations

The NOAEL is given in milligrams per kilogram per day (mg/kg-day) for oral (dietary) exposure, or in nanograms per cubic meter (ng/m^3), mg/kg-day, milligrams per liter (mg/L), or milligrams per cubic meter (mg/m^3) for inhalation exposure. We preferentially used inhalation NOAELs when available, as they most closely model the types of exposures examined.

Inhalation NOAELs given as air concentrations in mg/L were converted to concentrations in ng/m^3, as shown in equation (1).

$$\text{NOAEL (ng/m}^3) = \text{NOAEL (mg/L)} \times 10^6 \text{ ng/mg} \times 10^3 \text{ L/m}^3 \quad (1)$$

Inhalation doses given in mg/kg-day were converted to air concentrations in ng/m^3 using equation (2), where BW and BR are the average body weight and breathing rate of the population in question (70 kg adult male and one-year-old child). For this conversion, absorption of the compound via inhalation was assumed to be equivalent to absorption via ingestion, thus the factor of 100%, according to standard U.S. EPA methodology.[253] We chose a single point estimate of exposure using exposure parameters previously developed for the two populations (see Table A-1).[254] When inhalation studies were not available, the same method was used to convert dietary NOAELs to inhalation NOAELs, a procedure commonly used by U.S. EPA and DPR to estimate an inhalation NOAEL when inhalation data are not available.

Table A-1: Exposure Parameters

	Body Weight (BW) in kg	Breathing Rate (BR) in m^3/day
Adult male	70	18
One-year-old child	7.6	4.5

Source: Reference 252.

$$\text{NOAEL (ng/m}^3) = \frac{\text{NOAEL (mg/kg - day)} \times \text{BW(kg)} \times 10^6 \text{ ng / mg}}{\text{BR (m}^3 \text{ / day)}} \times 100\% \qquad (2)$$

Calculation of Reference Exposure Levels (RELs) from NOAELs

Conversion of the “acceptable” concentration of a chemical in air for laboratory animals into one for adult humans requires modifying the test-animal NOAEL with two uncertainty factors:

- An interspecies factor (UF_{inter}) of ten to allow for the differences between laboratory animals and humans. For example, if the dose that results in no observed effect (the NOAEL) in a rat study were 3 mg/kg-day and no human studies on acute toxicity were available, the “acceptable” dose for a human would be lowered to 0.3 mg/kg-day. In practice, the relative sensitivity of laboratory animals compared to humans is different for each chemical. In cases where both human data and rat data are available, this factor ranges from humans being 1,000 times more sensitive than rats to one tenth as sensitive.[255] The factor of ten—to allow for ten times greater human vulnerability—is the most commonly chosen, but is not sufficiently protective for all chemicals.
- An intraspecies factor (UF_{intra}) of ten to allow for the differences between different human individuals. Genetic differences exist in humans’ ability to detoxify and eliminate toxic substances. A good example is the 80-year-old who has smoked two packs of cigarettes a day for 60 years and escapes lung cancer compared to the 25-year-old who acquires multiple chemical sensitivity after a single exposure to a toxic substance. The intraspecies uncertainty factor attempts to take these differences into account. However, the genetic variability in humans’ ability to detoxify foreign substances is known to exceed a factor of ten in at least one situation.[256]

Acute and sub-chronic RELs for a 70 kg adult male were obtained by dividing the NOAEL (in ng/m^3) by the intraspecies and interspecies uncertainty factors, as well as any other modifying factors, as shown in equation (3). Other uncertainty factors (UF_{other}) are used when exposure/toxicity studies do not produce a NOAEL, but only a LOAEL, i.e. toxicity is observed at all doses tested. Under these circumstances, the LOAEL (or LOEL) is normally divided by an additional uncertainty factor of three to ten to obtain a REL that more closely reflects a NOAEL.

$$\text{Adult REL (ng / m}^3) = \frac{\text{NOAEL (ng / m}^3)}{UF_{intra} \times UF_{inter} \times UF_{other}} \qquad (3)$$

For children, the Federal Food Quality Protection Act (FQPA) requires U.S. EPA to use an additional child uncertainty factor (FQPAF) of two to ten to allow for the fact that infants and children are particularly susceptible to toxins. If additional information is available indicating that children are *not* especially susceptible to toxic effects from the chemical, this uncertainty factor might be less than ten. If no data are available on toxic effects that might be specific to children (e.g., developmental neurotoxicity), the law requires the factor of ten to be used. DPR does not use this additional uncertainty factor in its risk assessments, a fact that comes into play when DPR has conducted a risk assessment for a particular pesticide (e.g., metam sodium/MITC and methyl bromide) but U.S. EPA has not yet conducted a risk assessment under the new FQPA requirements. For these chemicals, the need for an additional uncertainty factor for children has not yet been assessed, and the RELs may be underprotective.

Acute and sub-chronic RELs for a one-year-old child were obtained by dividing the NOAEL (in ng/m^3) by the appropriate intraspecies and interspecies uncertainty factors, as well as any other modifying factors and any FQPA factor for children, as shown in equation (4).

$$\text{Child REL (ng / m}^3) = \frac{\text{NOAEL (ng / m}^3)}{UF_{intra} \times UF_{inter} \times UF_{other} \times \text{FQPAF}} \qquad (4)$$

Table A-2 provides RELs for each of the chemicals evaluated in this report and the specific parameters used to calculate these values.

Calculation of Hazard Quotients (HQs)

Hazard quotients (HQs) presented in Table 2-1 (see page 22) were calculated by dividing measured air concentrations of a particular chemical by the appropriate REL. For acute exposures, the maximum measured concentration was compared to the acute REL, according to equation (5).

$$\text{Acute HQ} = \frac{\text{Maximum Concentration (ng/m}^3\text{)}}{\text{Acute REL}} \quad (5)$$

The maximum concentration was measured as the total mass of pesticide trapped by the sampling device over the course of 2–12 hours, depending on the pesticide. Thus, this maximum measured concentration is a time-weighted average over the sampling period. Shorter-term peak exposures are higher than the maximum concentration measured by this sampling method.

For sub-chronic exposures, air monitoring data taken over nine days to several months were averaged and compared with sub-chronic RELs according to equation (6).

$$\text{Sub-chronic HQ} = \frac{\text{Avg. Seasonal Concentration (ng/m}^3\text{)}}{\text{Sub-chronic REL}} \quad (6)$$

Table A-2: Reference Exposure Levels and Toxicities of Pesticides Evaluated

Parameter	Chlorpyrifos	Diazinon	1,3-Dichloro-propene (Telone)	Methyl Bromide	Metam sodium/MITC	Molinate
Uncertainty factors[a]	10, 10, 1	10, 10, 3[b]	10, 10, 1	10, 10, 1	10, 1, 1[c] 10, 10, 3[d, b]	10, 10, 2.1[b]
FQPA factor	10	1	1	Not established	Not established	10
Acute NOAEL	0.1 mg/kg-day	0.026 mg/kg-day	40.4 mg/m^3	81.5 mg/m^3	0.66 mg/m^3	1.8 mg/kg-day
Acute adult REL (ng/m^3)	3,880	330	404,000	815,000	66,000	23,300
Acute child REL (ng/m^3)	170	145	176,000	354,000	66,000	1,010
Toxic endpoint	Neurotoxicity: cholinesterase inhibition	Neurotoxicity: cholinesterase inhibition	Body weight reduction	Developmental toxicity—gall bladder agenesis	Eye irritation	Developmental neurotoxicity
Sub-chronic NOAEL	0.1 mg/kg-day	0.026 mg/kg-day	27.6 mg/m^3	0.78 mg/m^3	0.89 mg/m^3	0.00064 mg/L
Sub-chronic adult REL (ng/m^3)	3,880	330	276,000	7,800	3,000	3,000
Sub-chronic child REL (ng/m^3)	170	145	120,000	3,400	1,300	130
Toxic endpoint	Neurotoxicity: cholinesterase inhibition	Neurotoxicity: cholinesterase inhibition	Degeneration and necrosis in the nasal epithelium	Neurotoxicity	Increased atrophy of the nasal epithelium	Decreased number of implants and increased percentage of abnormal sperm. Testicular degeneration. Decreased brain weights observed in offspring at all dose levels tested in a two-generation dietary study.
Data source	U.S. EPA RED, reference 137	U.S. EPA RED, reference 139	DPR risk assessment, reference 134	DPR risk assessment, reference 133	DPR risk assessment, reference 132	U.S. EPA Prelim. risk assessment, reference 140

a. Given in the order: intraspecies, interspecies, and other modifying factors.

b. No NOAEL was available, with toxic effects observed at all doses tested. The LOAEL was used instead with an additional uncertainty factor.

c. Acute uncertainty factors. A human study was available, so no interspecies uncertainty factor was required. Because the endpoint was eye irritation and not a systemic effect, the adult and child RELs are the same.

d. Sub-chronic uncertainty factors.

Additional notes on HQs and RELs by pesticide

Chlorpyrifos

Acute and sub-chronic RELs for chlorpyrifos were based on the short and intermediate-term inhalation NOAEL for chlorpyrifos of 0.1 mg/kg-day, derived from two separate 90-day rat inhalation studies where no effects were observed at the highest dose tested. At higher oral doses of 0.3 mg/kg-day (LOAEL), 43% plasma and 41% red blood cell cholinesterase reductions were observed in animals. The lung absorption was assumed to be 100% of oral absorption.[257]

Diazinon

Acute and sub-chronic RELs for diazinon were based on an "anytime" inhalation Reference Concentration (RfC) of 0.026 mg/kg-day, determined by U.S. EPA in a 21-day rat study.[139] This RfC is applied to any exposure period.

1,3-Dichloropropene

Conversion from parts per trillion by volume (pptv) to ng/m^3 for 1,3-dichloropropene was carried out using equation (7).

$$ng/m^3 = \frac{pptv \times (110.0g/mol) \times (1atm)}{(0.08205L \cdot atm/mol \cdot °K) \times (298°K)} = pptv \times 4.50 \qquad (7)$$

$$\mu g/m^3 = ppbv \times 4.50$$

Methyl bromide

The range of HQs for sub-chronic exposures was calculated from seasonal air monitoring conducted in Monterey and Santa Cruz Counties in 2000 and 2001. Results from Chular and Oak schools were excluded because the monitoring period did not correspond to methyl bromide use in the surrounding three-mile area. As such, these values were not representative of typical seasonal exposures during a methyl bromide fumigation season.

Conversion from parts per trillion by volume (pptv) to ng/m^3 for methyl bromide was carried out using equation (8).

$$ng/m^3 = \frac{pptv \times (94.9g/mol) \times (1atm)}{(0.08205L \cdot atm/mol \cdot °K) \times (298°K)} = pptv \times 3.88 \qquad (8)$$

$$\mu g/m^3 = ppbv \times 3.88$$

MITC/ metam sodium

Acute HQs for MITC were calculated from results of application site monitoring for both sprinkler and shank applications conducted in Kern County in 1993 and 1995 under currently allowed use conditions. DPR states that results of one of these studies should be interpreted with caution since it is possible but not certain that an inversion condition developed during application.[132] We include it because applications are not always halted when inversion conditions develop, and inversion conditions may develop after application is complete. The highest acute HQs provide an estimate of exposures at very close range, such as might be experienced by workers in adjacent fields (since no buffer zones are in place for workers) or by residents near application sites without buffer zones. DPR recommends but does not mandate a 500-foot buffer zone between occupied structures and metam sodium applications.

The MITC sub-chronic HQ range was calculated from results of seasonal air monitoring studies conducted in Kern County in 1993, 1997 and 1998 under currently allowed application conditions.[132] Results from seasonal monitoring in Lompoc in summer of 1999 were excluded because this monitoring was not conducted during the peak use period for the area.[258]

Conversion from parts per trillion by volume (pptv) to ng/m^3 for methyl isothiocyanate (MITC) was carried out using equation (9).

$$ng/m^3 = \frac{pptv \times (73.12g/mol) \times (1atm)}{(0.08205L \cdot atm/mol \cdot °K) \times (298°K)} = pptv \times 2.99 \qquad (9)$$

$$\mu g/m^3 = ppbv \times 2.99$$

Conversion from parts per trillion by volume (pptv) to ng/m^3 for methyl isocyanate (MIC) was carried out using equation (10).

$$ng/m^3 = \frac{pptv \times (57.05g/mol) \times (1atm)}{(0.08205L \cdot atm/mol \cdot °K) \times (298°K)} = pptv \times 2.33 \qquad (10)$$

$$\mu g/m^3 = ppbv \times 2.33$$

Molinate

An acute inhalation NOAEL was not available for molinate, so the REL was calculated from the acute dietary NOAEL using equation (2).

The sub-chronic adult REL was based on the observable effects of lowered sperm counts and abnormal sperm.[140] Such effects are not observable in children, but damage to the testes is still likely in children since this is a target site for the toxic effects of molinate.

Estimation of lifetime cancer risk from seasonal exposures to 1,3-dichloropropene

To estimate the risk of cancer from exposure to a substance over a 70-year lifetime, one must know the following:

- The **average concentration** of the substance in air during the monitoring period.
- The **exposure frequency,** or the fraction of a year in which concentrations are estimated to equal the average concentration measured during the monitoring period. This number can be estimated using pesticide use data.
- The **average annual concentration** of the substance in air, determined from the exposure frequency and the average concentrations observed during the monitoring period.
- The **cancer potency factor, Q*,** determined from toxicity studies. For 1,3-dichloropropene, DPR determined that Q* = 5.50 x 10^{-2} (mg/kg-day)$^{-1}$.[134]

Details for each calculation are shown below and the results are presented in Table A-3.

Determination of average air concentrations of 1,3-dichloropropene during the application season

Seasonal air monitoring was conducted by ARB in Kern, Monterey, and Santa Cruz counties in 2000 and 2001 for 7 to 9 week periods (see Table A-3). Average air concentrations of 1,3-dichloropropene calculated by DPR[259] in parts per billion (ppb) were converted to ng/m^3 using equation (7) and a conversion factor. DPR assigned the value of one-half the limit of detection (LOD) to samples below the LOD for each 1,3-dichloropropene isomer. The midpoint between the LOD and the limit of quantitation (LOQ) was substituted for any concentration below the LOQ, but above the LOD.

Determination of exposure frequency

Exposure frequency was calculated based on the fraction of the year 2000 (by month) when reported 1,3-dichloropropene use was at least half the average of reported monthly use during the monitoring period within a 3-mile radius of the monitoring site. The complete set of 2001 pesticide use data was not available for use in this analysis so the 2000 data were used for both years. When calculating the average annual air concentration resulting from three days of exposure 300 feet from a fumigated field, the exposure frequency was assumed to be three days per 365 days. From the application site monitoring study, the average concentration over three days was found to be 32,800 ng/m^3 downwind of the field (see Table A-8).

Determination of average annual 1,3-dichloropropene air concentration and exposure

Average annual air concentrations were calculated by multiplying the air concentrations determined at the monitoring stations averaged over the entire seasonal air monitoring period (7 to 9 weeks) by the exposure frequency, according to equation (11).

$$\text{Avg. annual conc. (ng/m}^3) = \left(\text{Avg. conc. during monitoring period}\right) \times \left(\text{Exposure frequency}\right) \qquad (11)$$

Annual exposure to 1,3-dichloropropene was calculated by multiplying the average annual air concentration by the adult inhalation rate of 0.28 m^3/kg-day, according to equation (12). This calculation assumes the annual average air concentrations remain at the same level as the base year from which monitoring results were used.

$$\text{Annual exposure (mg/kg - day)} = \left(\text{Avg. annual conc. (ng/m}^3) \times 10^{-6}\,\text{mg/ng}\right) \times \left(0.28\ \text{m}^3\,/\text{kg - day}\right) \qquad (12)$$

Determination of lifetime cancer risk from 1,3-dichloropropene exposures

To obtain the lifetime (70-year) cancer risk, the average annual exposure to 1,3-dichloropropene in mg/kg-day is multiplied by the potency factor (Q*) of 5.50 x 10^{-2} $(mg/kg/day)^{-1}$, according to equation (13).

$$\text{Lifetime cancer risk} = \left(\text{Annual exposure (mg/kg - day)}\right) \times \left(5.5 \times 10^{-2}\,(\text{mg/kg - day})^{-1}\right) \qquad (13)$$

Table A-3: Seasonal Monitoring Results and Cancer Risk Estimates for 1,3-Dichloropropene

Location	Average Air Conc. during Seasonal Monitoring in 2000 (ng/m^3)[b]	Exposure Frequency	Estimated 2000 Average Annual Air Concentration (ng/m^3)	Estimated Lifetime Cancer Risk per Million (2000 Basis)	Average Air Conc. during Seasonal Monitoring 2001 (ng/m^3)[b]	Estimated 2001 Average Annual Air Concentration (ng/m^3)	Estimated Lifetime Cancer Risk per Million (2001 Basis)
Living 300 feet from fumigated field in a region of high use[a]	CRS: 8,100 NF: 32,800	CRS: 0.42 ARV: 0.33 0.00822	3,402 270	52 4	ARV: 4,800 NF: 32,800	1,584 270	24 4
Cotton Research Station—Shafter	8,100	0.42	3,402	52	200	84	1.3
Arvin High School	not tested	0.33	---	---	4,800	1,584	24
Vineland School	1,200	0.33	396	6.1	2,300	759	12
Mettler Fire Station	2,100	0.25	525	8.1	949	237	3.6
Mountain View School	1,900	0.17	323	5.0	904	154	2.4
Shafter Air Station	500	0.083	42	0.6	not tested	---	---
Average of Kern Sites	**2,760**	**0.26**	**938**	**14.4**	**1,831**	**564**	**8.8**
MacQuiddy School	not tested	0.17	---	---	1,727	294	4.5
Pajaro M. School	294	0.17	50	0.8	400	68	1.0
Chular School	400	0.67	268	4.1	200	134	2.1
Salsepuedes School	50	0.25	12.5	0.2	200	50	0.8
La Joya School	40	0.083	3.3	0.1	300	25	0.4
Salinas downtown	40	0.083	3.3	0.1	200	17	0.3
Average of Coastal Sites	**154**	**0.24**	**67**	**1.0**	**504**	**98**	**1.5**

a. Peak exposure risk estimate assumes yearly exposure at the highest average level measured at a seasonal monitoring site (Cotton Research Station—Shafter in 2000 and Arvin in 2001) plus an additional three days of exposure per year at the near-field (NF) three-day average level of 32,800 ng/m^3 at a distance 300 feet downwind of a field treated with 1,3-dichloropropene (see Table A-8 below). This exposure is equivalent to an average daily annual exposure of 90 ng/m^3. The three days of exposure 300 feet from a fumigation carries a risk of 4.2 in 1,000,000 excess cancers, independent of other exposures.

b. Source: Reference 173.

Appendix 3: Air Monitoring Methods and Data

How application site monitoring is done

Application site monitoring involves sampling air near a pesticide-treated field during and after an application to determine how the pesticide air concentration changes as a function of time after application. This type of study focuses on a single pesticide. As expected, the highest concentrations of airborne pesticides occur close to application sites.

Air samplers are typically placed 30–75 feet from the field boundary on all sides of the field (see Figure A-1), and a weather station is placed nearby to monitor wind speed and direction and temperature. One method of sampling uses an air pump to pull air through a dust and pesticide-trapping filter at a calibrated rate, with the filters changed periodically over the course of a three to ten day sampling period. Analysis of the sample filter gives the mass of pesticide trapped on the filter in nanograms. Based on the flow rate of air through the sampler (in cubic meters per minute) and the sampling period (in minutes), the average pesticide air concentration during the sampling period in nanograms per cubic meter (ng/m^3) is determined. For fumigant sampling, the preferred method of sampling is to use evacuated stainless steel canisters to capture an air sample through a calibrated flow valve which is set to fill the canister at a pre-determined rate. The gas inside the canister is then analyzed directly. Because the drifting "plume" of volatilized pesticide has a three-dimensional concentration gradient, results are dependent on distance of the monitoring station from the field, wind speed and direction, and height of sampler.

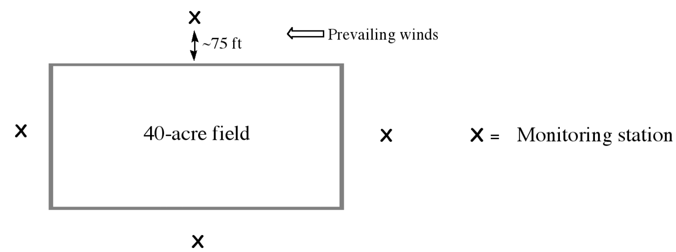


Figure A-1
Diagram showing typical sampler locations for an application site monitoring study.

Calculations

The data summarized in this report were taken directly from ARB monitoring reports, generally available in full on the DPR website.[147] Two quantities were calculated from the data: 1) a concentration representing the sum of the total mass of pesticide collected on all samplers for a single time period, and 2) the percent of drift occurring per sample period. All plots of the data were created by PAN.

Determination of a sum concentration

The purpose of this calculation was to estimate the concentration at a downwind site if the wind were blowing from a single direction throughout the sampling period. This number was obtained by summing the total mass of pesticide collected on all samplers (#1, #2, #3…#n) during a particular sampling period and dividing this value by the average volume of air passing through the samplers (V_{avg}) during the time period in question, according to equation (14).

$$\text{Sum Conc.} = \frac{\sum \text{mass}_{\#1} + \text{mass}_{\#2} + \text{mass}_{\#3} \ldots + \text{mass}_{\#n}}{V_{avg}} \quad (14)$$

For sites with two co-located samplers, the masses from the two samplers were averaged and the average mass was used in the calculation to obtain the total mass.

Determination of percent drift as a function of time

The percent of drift occurring during a single sampling period as a function of time was determined by summing the total mass of pesticide collected on all samplers over the course of a single sampling period and dividing by the total mass of pesticide collected on all samplers over the entire sampling period. Equation (15) shows the calculation for the first sampling period of a sequence.

$$\%\ \text{of Drift}_{\#1} = \left(\frac{\sum \text{mass}_{\#1}\,(\text{all samplers})}{\sum \text{mass}_{\#1} + \text{mass}_{\#2} + \text{mass}_{\#3} \ldots + \text{mass}_{\#n}}\right) \times 100\% \quad (15)$$

For sites with two co-located samplers, the masses from the two samplers were averaged and the average mass was used in the calculation to obtain the total mass.

How seasonal ambient air monitoring is done

Seasonal ambient air monitoring involves sampling air in regions of high pesticide use during a period of maximum use in a particular geographic area. ARB usually places samplers on fire stations and schools in towns close to the location of pesticide applications, but not immediately adjacent to fields (from several hundred yards to several miles away). This type of study can focus on a single pesticide or survey for many pesticides at once. Monitoring is carried out 4–5 days per week for up to eight weeks during the season of peak use for the pesticide. Concentrations measured at these locations are typically lower than those measured next to application sites.

For any type of sampling, wind speed and direction, weather, and temperature are recorded during the entire sampling period. Temperature affects the rate of volatilization of a pesticide from the application site, and prevailing winds dictate the direction traveled by drift moving off-site.

Application conditions and monitoring data for each chemical

Data for Chlorpyrifos

Table A-4: Application Site Monitoring Conditions for Chlorpyrifos*

Location of application	Tulare County
Date of application	June 4 and 5, 1996
Time of application	06:30–10:30 (June 4) and 04:30–10:30 (June 5)
Type of application	Ground-rig blower
Distance of monitoring stations from field boundaries	North, 57 feet; East, 42 feet (two co-located samplers); and South, 30 feet. West sampler was stolen and not replaced during the study.
Size of treated area	60 acres, orange grove
Product applied	Lorsban 4E
Product application rate	1.5 gallons per acre in 750 gal of water
Active ingredient (AI)	Chlorpyrifos, 50%
Vapor pressure of AI	1.7 x 10^{-5} mm Hg at 25°C
AI application rate	6 lbs chlorpyrifos per acre (3–4.5 lbs/acre is typical for oranges)
Total amount of AI applied	360 lbs
Temperature range during first 24 hours	Not reported in summary data, but 60–105°F is common at this time of year in Tulare County.
Winds	Light from the southeast at application start, shifting to high winds from the south and west 4–5 hours after start of first application. Winds light and from the east-southeast during second application.

*Source: Reference 194.

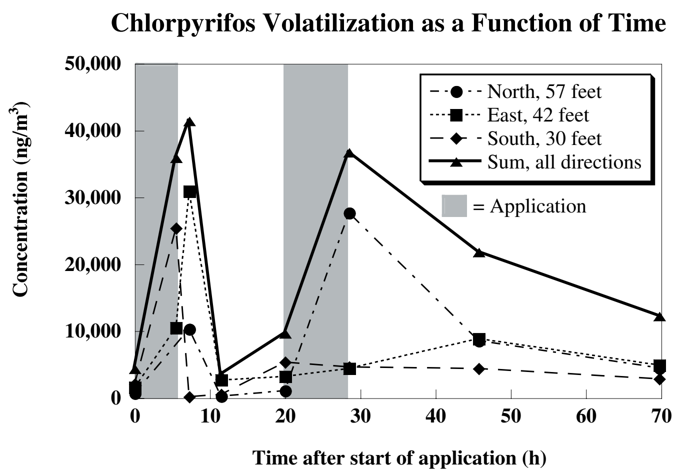


Table A-5: Application Site Monitoring Data for Chlorpyrifos*

			Concentration (ng/m^3)				
Sampling Period	**Direction Wind Coming From**[a]	**Time after Start of Application (h)**	**North, 57 feet**	**East, 42 feet**[b]	**South, 30 feet**	**Sum, all directions**	**% Drift per Period (by mass)**[c]
Background	SE	NA	690	1,570	2,070	4,330	---
1	SE	5.5	8,580	10,500	25,400	44,480	17.85
2	S	7.25	10,300	30,950	160	41,410	4.98
3	W/NW	11.5	250	2,680	510	3,440	1.04
4	SE/NW	20	1,100	3,200	5,320	9,620	7.06
5	SE	28.5	27,700	4,410	4,620	36,730	22.02
6	W/E/SE	45.75	8,550	8,850	4,390	21,790	26.58
7	W/E/SE	69.75	4,470	4,905	2,840	12,215	20.48
		3-day average	**8,707**	**9,356**	**6,177**		**100.00**

*Source: Reference 194.

a. Underlined wind direction is the predominant one, if any.

b. Average of two co-located samples.

c. See page 63.

Data for Diazinon

Table A-6: Application Site Monitoring Conditions for Diazinon*

Location of application	Kings County (Range, 21E; Township, 17S; Section 16)
Date of application	January 27, 1998
Time of application	09:30–13:30
Type of application	Ground rig spray (blower)
Distance of monitoring stations from field boundaries	North, 75 feet; East, 48 feet; South, 72 feet; West, 72 feet
Size of treated area	40 acres, dormant peach orchard
Product applied	Diazinon 50W, Clear Crop
Product application rate	4 lbs Diazinon 50W per acre in 200 gallons of water
Active ingredient (AI)	Diazinon, 50%
Vapor pressure of AI	8.47 x 10^{-5} mm Hg at 20°C
AI application rate	2 lbs diazinon per acre (1.5–2.5 lbs/acre is typical for peaches)
Total amount of AI applied	80 lbs
Temperature range during first 24 hours	Not reported in summary data, but possibly available as part of weather data from ARB.
Winds	Variable, ranging from light winds out of the southeast, shifting to strong winds out of the northwest approximately 8 hours after application.
Weather conditions	Overcast during background monitoring. Clear through first four samples, overcast with occasional rain and fog for the remaining monitoring periods.

*Source: Reference 197.

Diazinon Volatilization as a Function of Time

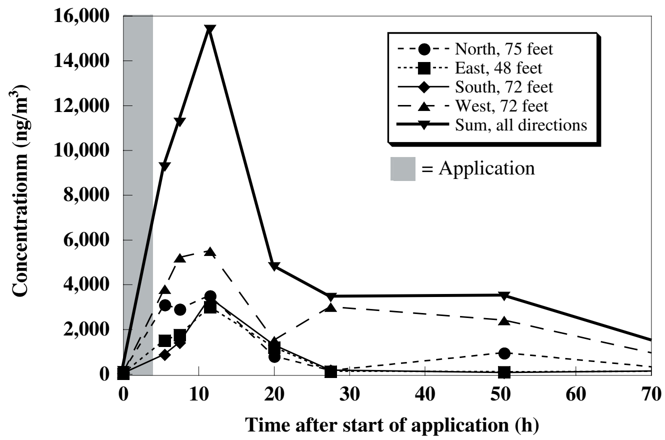


Table A-7: Application Site Monitoring Data for Diazinon*

			Concentration (ng/m³)					
Sampling period	**Direction Wind Coming From[a]**	**Time after Start of Application (h)**	**North 75 feet**	**East 48 Feet**	**South 72 feet**	**West 72 feet**	**Sum, all directions**	**% Drift per Period (by mass)[b]**
1, Background	E/SE/S	NA	75	29	28	34	166	---
2	E/SE/S/SW	5.5	3,100	1,500	870	3,800	9,270	16.6
3	N/SE	7.5	2,900	1,750	1,400	5,200	11,250	7.3
4	SW/W	11.5	3,500	3,000	3,400	5,500	15,400	21.0
5	NW/W	20	800	1,200	1,300	1,500	4,800	12.9
6	SE/W/E	27.5	150	117	170	3,000	3,437	8.6
7	E/SE	50.5	940	87	58	2,400	3,485	25.6
8	SE/E/NE	74.5	170	125	140	600	1,035	8.0
		3-day average	**1,651**	**1,111**	**1,048**	**3,143**		**100.0**

*Source: Reference 197.

a. Underlined wind direction is the predominant one, if any.

b. See page 63

Data for 1,3-Dichloropropene (Telone)

Table A-7: Application Site Monitoring Conditions for 1,3-Dichloropropene*

Location of application	Monterey County
Date of application	September 15, 1993
Time of application	10:30–13:45, tarp sealing complete at 14:30
Type of application	Soil injection to a depth of 18 inches
Distance of monitoring stations from field boundaries	NW and SE, 300 feet; C-1 and C-2, in nearby town, but exact distance not reported
Size of treated area	11.1 acres
Product applied	Telone II
Product application rate	11.62 gallons/acre
Active ingredient (AI)	*cis-* and *trans-*1,3-dichloropropene, 94%
Vapor pressure of AI	29 mm Hg at 25°C
AI application rate	110 lbs of 1,3-dichloropropene per acre (75–250 lbs/acre is typical)
Total amount of AI applied	1,223 lbs
Temperature range during first 24 hours	Not reported in summary data, but possibly available as part of weather data from ARB.
Winds	Predominantly out of the WNW.

*Source: Reference 172.

1,3-Dichloropropene Volatilization as a Function of Time

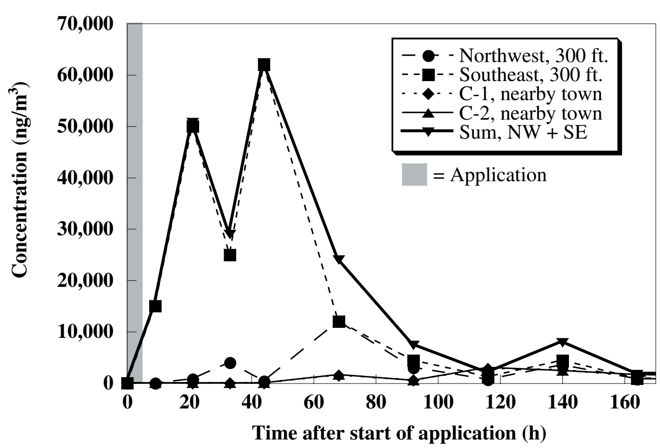


Table A-8: Application Site Monitoring Data for 1,3-Dichloropropene*

			Concentration (ng/m^3)					
Sampling Period[a]	Direction Wind Coming From[b]	Time after Start of Application (h)	Northwest 300 feet	Southeast 300 feet	C-1	C-2	Sum, NW + SE	% Drift per Period (by mass)[d]
1	W/SW/NW	9	<LOD (148)	15,000	<LOD (148)	<LOD (148)	15,000	5.8
2	WNW/SW/NW	21	770	50,000	<LOD (148)	<LOD (148)	50,770	21.1
3	W/NW/S/E/N	33	4,000	25,000	<LOD (148)	<LOD (148)	29,000	11.6
4	W/NW/SW	44	390	62,000	<LOD (148)	<LOD (148)	62,390	24.0
5	WNW/SW/SE	68	12,000	12,000	1,500	1,600	24,000	19.2
6	WNW/ESE/E	92	3,000	4,400	560	520	7,400	5.9
7	WNW/E/SE/S	116	700	1,200	2,800	3,000	1,900	1.5
8	WNW/SE/NW/E	140	3,500	4,400	2,600	2,400	7,900	6.3
9	WNW/W/SE/SW	164	800	900	1,300	1,600	1,700	1.4
10	NW/E/W/SE/SW	188	910	910	1,200	1,200	1,820	1.5
11	NW/W/E/SE	212	450	490	630	660	940	0.8
12	NW/E/W	236	NA[e]	1,200	1,400	1,400	1,200	1.0
		3-day average[c]	**3,447**	**32,800**	**359**	**379**		**100.00**
		10-day average[c]	**2,418**	**14,792**	**1,024**	**1,056**		

*Source: Reference 172.

a. No background samples were reported.

b. Underlined wind direction is the predominant one, if any.

c. To calculate the average using samples with detections less than the LOD, concentrations for these samples were set at half the LOD. This practice is commonly used to estimate concentrations below the detection limit.[257]

d. See page 63.

e. NA = not available. Sampling pump malfunctioned.

Table A-9: Locations for Seasonal Monitoring of Methyl Bromide and 1,3-Dichloropropene

County/Year	Kern, 2000[a]	Kern, 2001[b]	Monterey/Santa Cruz, 2000[c]	Monterey/Santa Cruz, 2001[d]
Monitoring Period	July 19 to Aug. 31, 2000 (7 weeks)	June 30 to Aug. 30, 2001 (9 weeks)	Sept. 11 to Nov. 2, 2000 (7 weeks)	Sept. 8 to Nov. 7, 2001 (8 weeks)
Rural Monitoring Locations[e]	CRS, VIN, MET, MVS, SHF	CRS, VIN, MET, MVS	PAJ, CHU, SAL, LJS, SEL, OAK	MCQ, PAJ, CHU, SAL, LJS, SEL
Background Urban Location	ARB Station, Bakersfield	ARB Station, Bakersfield	Salinas Monitoring Station	Salinas Monitoring Station
Monitoring Schedule	4 week days/week	4 week days/week	4 week days/week	4 week days/week
Monitoring Equipment	Silcosteel cannisters	Silcosteel cannisters	Silcosteel cannisters	Silcosteel cannisters

a. Reference 173a.

b. Reference 173b.

c. Reference 173c.

d. Reference 173d.

e. Kern County monitoring locations include: CRS—Cotton Research Station in Shafter; ARV—Arvin High School; VIN—Vineland School near Arvin; MET—Mettler Fire Station; MVS—Mountain View School in Lamont; SHF—Shafter Air Monitoring Station. Monterey and Santa Cruz counties monitoring sites include: MCQ—MacQuiddy School near Salinas; PAJ—Pajaro Middle School near Watsonville; CHU—Chular School in Greenfield; SAL—downtown Salinas; LJS—La Joya School in Salinas; SEL—Salsepuedes School in Watsonville; OAK—Oak School in Greenfield.

Data for Metam Sodium/ MITC

Table A-10: Application Site Monitoring Conditions for MITC*

Location of application	Kern County
Date of application	August 3, 1993
Time of application	7:30 p.m. on 8/3/93 through 1:30 a.m. on 8/4/93
Type of application	Sprinkler application with watering in
Distance of monitoring stations from field boundaries	N, E, S, W: 16 feet NE, 266 feet; SE, 244 feet; SW, 250 feet; NW, 231 feet N, 488 feet; S, 488 feet
Size of treated area	20 acres
Product applied	Vapam®
Product application rate	100 gallons/acre
Active ingredient (AI)	Metam sodium, which breaks down to the active pesticide, methyl isothiocyanate (MITC)
Vapor pressure of AI	16 mm Hg at 25°C
AI application rate	318 lbs/acre (50–320 lbs/acre is typical for soil fumigations)
Total amount of AI applied	6,360 lbs
Temperature range during first 24 hours	63–102 °F
Winds	Winds predominantly from the NW and SW, 0–11 mph, but mostly light.

*Source: Reference 163.

Table A-11: Application Site Monitoring Data for MITC*

Sampling Period	Direction Wind Coming From[a]	Time Elapsed from Start of Application (h)[b]	Concentration (ng/m³) 1 North 16 ft	2 East 16 ft	3 South 16 ft	4 West 16 ft	5 NE 266 ft	6 SE 244 ft	7 SW 250 ft	8 NW 231 ft	9 North 488 ft	10 South 488 ft	% Drift per Period (by mass)[e]
1	S	6	7,325,500	6,398,600	234,117	245,479	6,308,900	132,158	14,083	71,461	3,946,800	7,325,500	56.43
2	E	7.5	1,611,610	433,550	917,930	1,536,860	1,097,330	< LOD (38,870)	624,910	1,533,870	1,414,270	1,611,610	4.60
3	NE, SW	13.5	NA[c]	3,139,500	529,230	532,220	1,638,520	106,743	72,059	132,158	148,603	NA	24.32
4	NW	19.5	30,199	137,540	316,940	36,478	< LOD (11,960)	19,465	19,854	< LOD (11,960)	< LOD (11,960)	30,199	2.40
5	NW, SW	25.5	140,829	714,610	439,530	< LOD (11,960)	141,726	126,477	< LOD (11,960)	< LOD (11,960)	< LOD (11,960)	140,829	4.24
6	SW	37.5	346,840	388,700	24,398	< LOD (5,980)	397,670	6,787	16,983	6,847	24,099	346,840	6.48
7	NW	49.5	23,352	54,717	59,800	< LOD (5,980)	17,193	23,472	< LOD (5,980)	< LOD (5,980)	NA[c]	23,352	0.91
8	SW	61.5	18,598	49,036	< LOD (5,980)	< LOD (5,980)	43,355	< LOD (5,980)	< LOD (5,980)	< LOD (5,980)	NA[c]	18,598	0.55
9	NW, W, N	73.5	< LOD (5,980)	6,817	6,847	< LOD (5,980)	< LOD (5,980)	< LOD (5,980)	< LOD (5,980)	< LOD (5,980)	NA[c]	< LOD (5,980)	0.06
4-day average[d] (ng/m³)			**1,356,704**	**1,258,119**	**316,099**	**587,759**	**1,377,813**	**69,184**	**149,578**	**436,084**	**1,383,443**	**66,970**	

*Source: Reference 163.

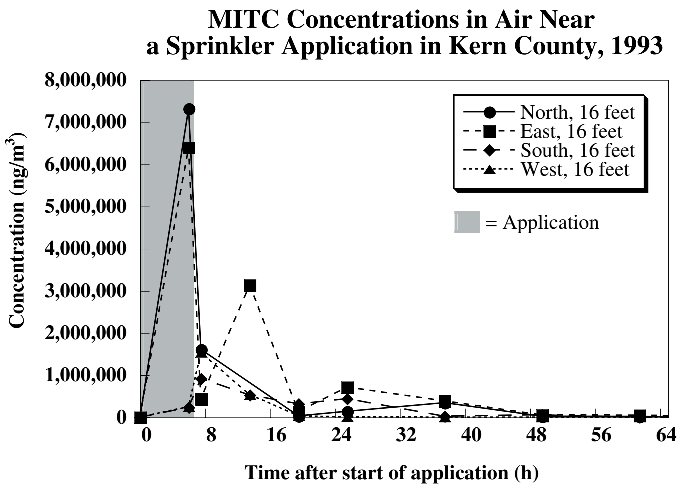
a. Underlined wind direction is the predominant one, if any.

b. Twelve-hour background samples taken at unspecified “north” and “south” positions and were below the LOD.

c. NA = not available, sample lost.

d. To calculate the average and median using samples with detections less than the LOD, concentrations for these samples were set at half the LOD concentration. This practice is commonly used to estimate concentrations below the detection limit.[257] LODs are variable because they are dependent on the sampling time.

e. See page 63.



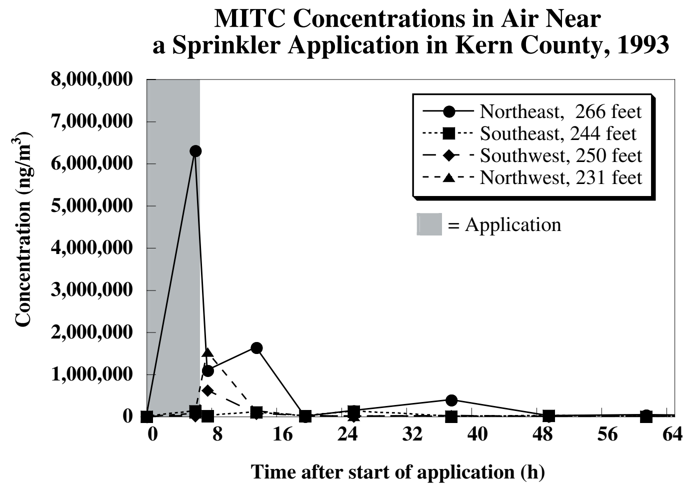


Table A-12: Comparison of MITC Application Site Monitoring Studies*

Date and Location	Monitoring Conducted by	Application Type	Application Rate (lbs AI/acre)	Acres Treated	Distance to Field Border (feet)	Maximum Concentration at Distance (ng/m³)[a]	Comment
Aug-93 Kern Co.	DPR	sprinkler	318	20.0	488	3,946,800	Representative of worst-case legal scenario: high application rate, high temperatures, sprinkler application. Good quality data.
Jun-99 Kern Co.	Merricks	sprinkler	320	80.0	488	839,000	High application rate, high temperatures. Maximum measured concentration is not a true maximum, since few or no samplers were placed directly downwind.
Jun-99 Kern Co.	Merricks	soil injection	320	79.0	488	839,800	High application rate, high temperatures. Maximum measured concentration is not a true maximum, since few or no samplers were placed directly downwind.
Aug-95 Kern Co.	ARB	soil injection, no sealing	155	80.0	39	250,000	Intermediate application rate, high temperatures, no sealing. Maximum measured concentration is not a true maximum, since no samplers were placed directly downwind.
May-92 Madera Co.	Rosenheck	sprinkler	305	6.7	406	856,000	High application rate, low temperatures. Maximum measured concentration is not a true maximum, since samplers were positioned perpendicular to wind direction.
Mar-93 Contra Costa Co.	ARB	soil injection, no sealing	57	95.0	45	242,000	Representative of best-case scenario with no soil sealing. Low application rate, low temperatures. Good quality data.
Jul-93 Kern Co.	ARB	soil injection, sealed[b]	155	85.0	60	880,000	Intermediate application rate, high temperatures, soil sealed.

*Source: Reference 132.

a. Maximum concentrations were chosen for distances that were as comparable as possible across the different studies, and do not necessarily represent the maximum concentration observed for the entire study.

b. DPR's summary of ARB's study indicated the soil was not sealed; however, in an errata note attached to the original monitoring report, ARB indicates the soil *was* sealed.

Data for Molinate

Table A-13: Application Site Monitoring Conditions for Molinate*

Location of application	Colusa County
Date and time of application	May 18, 1992, 11:00–13:30
Type of application	Aerial application of granules to planted rice field (probably flooded, but this is not explicitly stated)
Distance of monitoring stations from field boundaries	North (North-1), 30 feet; Northwest (North-2), 1/4 mile; South (South-1), 75 feet; South (South-2), 1/4 mile
Size of treated area	99 acres
Product applied	Ordram 10-G
Product application rate	50 lbs/acre
Active ingredient (AI)	Molinate, 10%
Vapor pressure of AI	5 x 10^{-3} mm Hg at 25°C
AI application rate	5 lbs of molinate per acre (2–5 lbs/acre is typical)
Total amount of AI applied	495 lbs
Temperature range	Not reported in summary data, but 55–90°F is common at this time of year in Colusa County. Skies mostly clear throughout the sampling period.
Winds	Variable, 2–12 mph, predominantly from the south for sampling periods 1–6, and predominantly from the north for the remainder.

*Source: Reference 198.

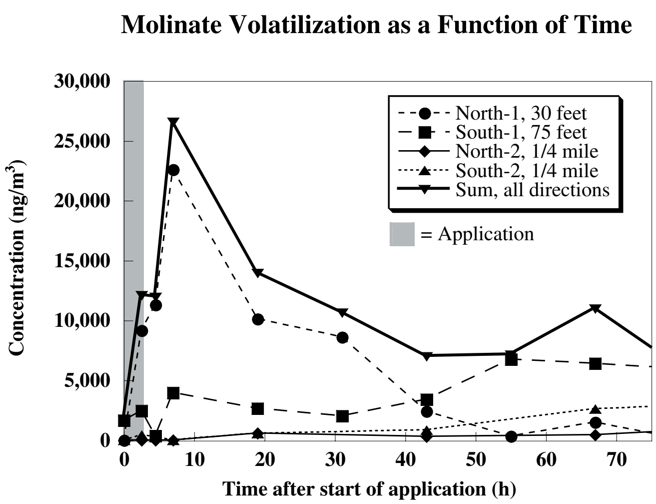


Table A-14: Application Site Monitoring Data for Molinate—Near-field*

Near-field			Concentration (ng/m³)			
Sampling Period	**Direction Wind Coming From[a]**	**Time after Start of Application (h)**	**North-1 30 feet**	**South-1 75 feet**	**Sum, all directions**	**% Drift per Period (by mass)[b]**
1, Background	S/SW	NA	< LOD (484)	1,650	1,650	---
2	S/SE	2.5	9,170	2,480	11,650	9.94
3	S/SW	4.5	11,320	370	11,690	9.83
4	SW/W	7	22,610	3,970	26,580	22.80
5	W/SW	19	10,140	2,650	12,790	11.46
6	S/SW/W	31	8,620	2,020	10,640	8.74
7	NW/W/NE	43	2,420	3,410	5,830	5.74
8	NE/NW	55	350	6,770	7,120	5.85
9	N/NE/NW	67	1,500	6,410	7,910	9.02
10	NE	79	120	5,980	6,100	5.01
11	NW/NE/E/W	94	3,280	6,270	9,550	11.60
		3-day average	**6,953**	**4,033**		**100.00**

*Source: Reference 198.

a. Underlined wind direction is the predominant one, if any.

b. See page 63.

Table A-15: Application Site Monitoring Data for Molinate—1/4 Mile

1/4 Mile			Concentration (ng/m³)		
Sampling Period	**Direction Wind Coming From[a]**	**Time after Start of Application (h)**	**North-2 1/4 mi.**	**South-2 1/4 mi.**	**Sum, all directions**
1, Background	S/SW	NA	NA	< LOD (526)	0
2	S/SE	2.5	< LOD (332)	450	450
3	S/SW	4.5	< LOD (263)	270	270
4	SW/W	7	< LOD (203)	< LOD (203)	0
5	W/SW	19	590	570	1,160
6 & 7	S/SW/W/NW/NE	43	300	860	1,160
8 & 9	N/NE/NW	67	450	2,620	3,070
10 & 11	NW/NE/E/W	94	1,320	3,240	4,560
		3-day average[b]	**430**	**1,159**	

*Source: Reference 198.

a. Underlined wind direction is the predominant one, if any.

b. To calculate the average using samples with detections less than the LOD, the concentrations for these samples were set at half the LOD. This practice is commonly used to estimate concentrations below the detection limit.[257] LODs are variable because they are dependent on the sampling time.

Appendix 4: Recent History of Methyl Bromide Restrictions in California

Year	Action
1987	Montreal Protocol signed, mandating phaseout of methyl bromide by 2005 in developed countries and by 2015 in developing countries.
1989	DPR proposes methyl bromide soil fumigation regulations that are rejected by California Office of Administrative Law but not resubmitted.
1992	DPR toxicology evaluation concl udes exposure levels must be reduced because of birth defects risk and a structural fumigation fatality caused by methyl bromide.
1992	Methyl bromide registrants required to conduct field-side air monitoring to serve as basis for setting buffer zones.
1993	Prop 65 listing of methyl bromide as a developmental toxicant limited to structural fumigations.
1993–94	DPR issues recommended permit conditions for methyl bromide field, structural, commodity, greenhouse, and potting-soil fumigation.
1995	DPR grants methyl bromide registrants exemption from mandated chronic inhalation toxicology testing.
1996	Methyl bromide registration extended in special State Senate hearing despite failure to submit toxicology tests by SB950-mandated deadline.
1996	DPR memo stating that exposure levels should be controlled near level of detection to prevent risk of sub-chronic effects becomes public.
1997	Environmental Working Group (EWG) raises concerns that charcoal tube sampling methodology used to determine buffer zones may be flawed and underestimate actual exposures.
1994–present	Community, environmental, and farmworker advocates question protectiveness of buffer zones.
1997	DPR monitoring shows that emissions for very high barrier tarp, drip, and bedded applications are much higher than predicted.
1998	Buffer zones for field fumigation methods listed above are increased. Schoolyards are still allowed to be used as part of a buffer zone.
1999	Friends of the Earth, Pesticide Watch, EWG, and Pesticide Action Network file suit seeking promulgation of field fumigation regulations. Court orders DPR to begin rulemaking.
1999–2000	DPR develops new regulations for methyl bromide soil fumigation.
1999	DPR acknowledges charcoal tube sampling problem and adjusts sampling results. Recoveries are found to be as low as 10%.
1999	DPR releases draft of methyl bromide risk assessment.
2000	National Academy of Sciences subcommittee reviews methyl bromide risk assessment and reaffirms DPR's choice of sub-chronic and acute reference exposure levels, but criticizes exposure assessment.
2000	Methyl bromide field fumigation regulation issued.
2000	Lawsuit filed by environmental and farmworker advocates charges that regulation was adopted without adequate buffer zone specifications or review of health and environmental impacts.
2000	Lawsuit filed by Ventura County Ag Association charges that regulations were adopted without adequate involvement of CDFA regarding impacts on farmers.
2001	Results of 2000 air monitoring confirm excessive sub-chronic exposure and strong correlation between amounts of methyl bromide used and observed air concentrations.
2001	CRLA Inc. files lawsuit in Monterey County demanding reduction of exposures at schools where excessive sub-chronic exposures were measured.
2001	Methyl bromide industry required to monitor area methyl bromide levels in Ventura and Santa Barbara counties as a condition of continuing registration.
2002	Court rules that DPR must redo methyl bromide regulations because DPR did not consult adequately with CDFA regarding impacts of methyl bromide regulations on agriculture.
2002	Results of 2001 air monitoring show that sub-chronic levels still exceeded RELs at a majority of monitoring sites and again shows a correlation with methyl bromide use.
2002	Settlement of Monterey County lawsuit requires DPR to consider sub-chronic exposures when methyl bromide regulations are revised and implement use restrictions around schools in lawsuit.
2003	DPR proposes relaxing the sub-chronic REL based on a controversial new industry-sponsored toxicology study. The issue remained unresolved as this report went to press.

References

1 *CA Pesticide Sales Data for 2000,* California Department of Pesticide Regulation, Sacramento, CA. The 2000 data are the most recent available at the time this report was written.

2 a) California requires all commercial pesticide applications to be reported to DPR, including agricultural, landscape, and structural. These data comprise the PUR data and are publicly available. Consumers and industry use approximately 150 million pounds of pesticide active ingredients annually that are not reported to the state.
b) *California Pesticide Use Reporting Data, 2000,* California Department of Pesticide Regulation, http://www.cdpr.ca.gov/docs/pur/purmain.htm.

3 This percentage was calculated from PUR data by determining the amount of pesticides applied as formulations that are unlikely to drift off-site during applications and subtracting from the total reported amount of pesticides applied in the state. The non-drift-prone formulations include granular pesticides (except molinate), gels/pastes/creams, microencapsulated products, impregnated materials, and pellet/tablet/cake/briquette formulations. The total amount of products applied in these formulations was 8.8 million pounds out of 187.6 million total pounds reported in 2000.

4 a) C. Lu and R.A. Fenske, Air and surface chlorpyrifos residues following residential broadcast and aerosol pesticide applications, *Env Sci Tech*, 1998, 32: 1386–90.
b) S. Gurunathan, M. Robson, N. Freeman, et al., Accumulation of chlorpyrifos on residential surfaces and toys accessible to children, *Env Health Persp*, 1998, 106: 9–16.

5 This is true even when the total excludes consumer and institutional pesticide use. The 1997 figures are used because this is the latest year for which both pesticide use and toxic release data are available for both California and the U.S.

6 a) *U.S. Environmental Protection Agency, Toxic Release Inventory,* 1997, http://www.epa.gov/triexplorer/chemical.htm.
b) *California Pesticide Use Reporting Data, 1997,* California Department of Pesticide Regulation, http://www.cdpr.ca.gov/docs/pur/purmain.htm.

7 a) *Pesticide Illness Surveillance Program Data 1991–1996*, California Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA, 1999.
b) *Pesticide Illness Surveillance Program Data 1998–2000*, California Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA, 2002.

8 a) M. Reeves, A. Katten, and M. Guzman, *Fields of Poison 2002: California Farmworkers and Pesticides,* Californians for Pesticide Reform, Pesticide Action Network, California Rural Legal Assistance Fund, and United Farm Workers (San Francisco, CA, 2002), http://www.panna.org/resources/documents/fieldsOfPoison2002.dv.html.
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