Surveillance Systems for Pesticide Intoxications

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The intent of this article is to provide an overview of surveillance systems dealing with pesticide intoxications. Surveillance, medical monitoring, and the components of a surveillance system are discussed. Information is presented on how to make a diagnosis of environmental or occupational pesticide intoxication, examples of different case definitions, and the steps in investigating a pesticide disease outbreak. Examples from various countries are used to illustrate acute pesticide intoxication surveillance, pesticide exposure surveillance, and medical monitoring of pesticide-exposed workers. Finally, a list of informational sources for pesticide toxicology, medical diagnosis and treatment, and surveillance data is provided. It is anticipated that this information will assist those individuals or organizations seeking to develop such a system, evaluate an existing system, or gain a better understanding of data derived from such systems. *Key words*: pesticides; surveillance systems; toxicology.

Depending on the overall goal of the system, surveillance can be interpreted in various ways. Definitions for both general and occupational surveillance are illustrated in citations from the National Institute for Occupational Safety and Health (NIOSH) and the International Labor Organization (ILO), respectively:

Public health surveillance is the ongoing systematic collection, analysis and interpretation of health data essential to the planning, implementation and evaluation of public health practices, closely integrated with the timely dissemination of these data to those who need to know. The final

link in the surveillance chain is the application of these data to prevention and control. A surveillance system includes a functional capacity for data collection, analysis and dissemination linked to public health programs.[1]

Occupational health surveillance is the ongoing systematic collection, analysis, interpretation and dissemination of data for the purpose of prevention. Surveillance is essential to the planning, implementation and evaluation of occupational health programs and control of work-related ill health and injuries and the protection and promotion of workers' health. Occupational health surveillance includes workers' health surveillance and working environment surveillance.[2]

These definitions illustrate some of the different attributes associated with surveillance systems: monitoring of health outcomes versus hazardous exposures, collecting information for a general population versus medical monitoring of a workforce, systems that focus on just environmental or occupational health conditions, and case ascertainment that may include active collection of health data and/or passive receipt of case reports.

For the purposes of this review, the term *surveillance* refers to the ongoing standardized system of data collection, analysis, interpretation, dissemination and, where appropriate, follow-up intervention for a given health outcome (in this case, pesticide intoxication). Surveillance systems are used for planning, implementing, and evaluating public health intervention and control programs. On a smaller scale, certain components of a surveillance system may be applied to a specific workplace population (which is referred to as a medical monitoring program). Furthermore, all surveillance systems should be periodically reviewed to ensure their optimal performance and usefulness. Examples of both environmental and occupational pesticide intoxication surveillance from various countries are highlighted. The scope of this review focuses on the general public health surveillance model for pesticide intoxications, with a brief discussion of medical monitoring of pesticide-exposed workers and the monitoring of pesticide exposures.

COMPONENTS OF A PESTICIDE INTOXICATION SURVEILLANCE SYSTEM

The key components and evaluation aspects of a public health surveillance system have been described by the Centers for Disease Control and Prevention in prior documents.[3,4] Furthermore, surveillance systems tend to detect mostly acute intoxications (with clearly defined exposures and rapid onset, subsequent disease). This is due to the difficulty in detecting the relatively long lag time between exposure onset and overt symptoms involved in chronic and long-term health conditions such as cancer. Adapting the general public health model, one would consider the following aspects of a surveillance system for acute pesticide intoxication (API):

Public Health Importance of API

Description of the extent, severity, and preventability of API for the surveillance target population. Is there a large number of known incident or prevalent cases? Is there a high disability or mortality rate for API among certain segments of the population? What are the lost-work days among occupational cases? Are there effective interventions that can prevent morbidity and mortality in this population? With API, access to health care providers familiar with pesticide-related disease may be a factor.

API Surveillance Description

- What are the objectives of the system? These may include detecting outbreaks, monitoring trends, generating hypotheses about API etiology, soliciting participants for research studies, and evaluating intervention efforts.
- Define the term "pesticide." The U.S. Environmental Protection Agency defines a pesticide as a substance to control pests such as insects, fungi, weeds, rodents, nematodes, algae, viruses, and bacteria. Some systems may want to focus on only a subgroup of all possible pesticide compounds.
- Describe the API case definition. The definition will usually include details about person, time, and place characteristics that will indicate an individual as a surveillance API case. These factors may include: pesticide exposure history, geographic restriction, time period, clinical symptoms, physical findings, laboratory results, and environmental sampling.
- What is the overall organization and flow of information. Figure 1 provides a flow diagram of a typical API surveillance system.
- Describe operation and components of system: target population, geographic catchment area, time period for data collection, type of information collected, data sources, storage and security of data, analytic methods, periodicity of reports, and dissemination plan.

Usefulness of the API surveillance system

What actions have been taken as a result of data from the surveillance system? Have results been used to make public health decisions or influence public health policy? Any other anticipated uses of the API surveillance system?

Evaluation of the API Surveillance System Attributes

Simplicity of structure and ease of operation. Manageable amount of information needed for case definition, reporting sources are few in number and easy to understand, simple data transmission and receipt of case reports, minimal staff training requirements, simple data analysis, reasonable number of case information users, and ease of information dissemination.

Flexibility. Ability to adapt to changing information needs or operating conditions.

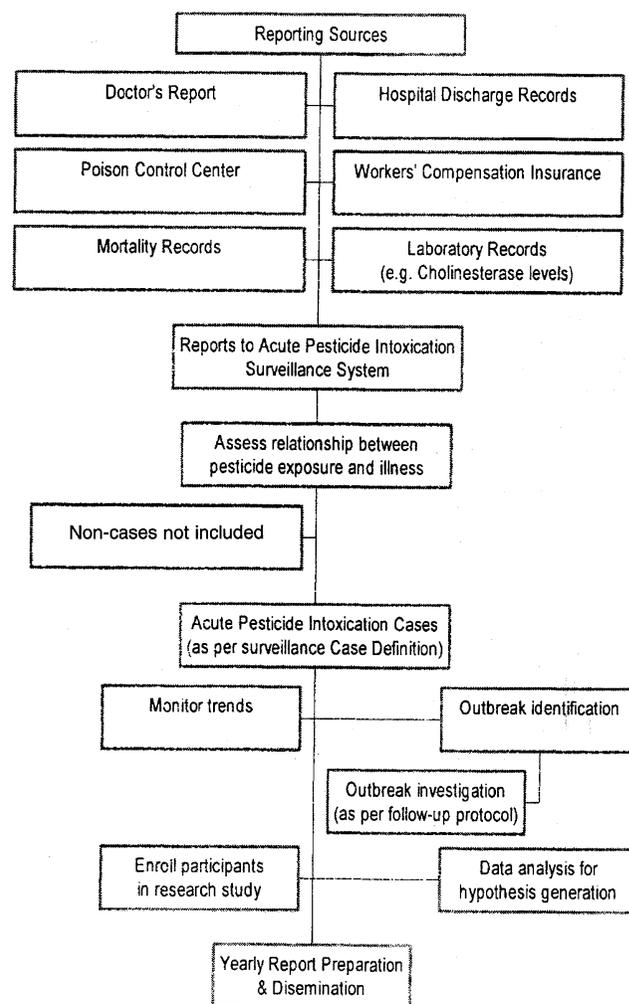*Acceptability.* Willingness of individuals, organizations

Figure 1—Flow diagram for acute pesticide intoxication surveillance system. Specify: target populataion, geographic area, time period. Overall system to be evaluated every two years.

Chart 1—Analysis of sensitivity and predictive value positive for acute pesticide intoxication (API) surveillance system.

	True API Case	True Non-case	Total
Surveillance API case	A	B	A + B
Surveillance non-case	C	D	C + D
Total	A + C	B + D	A + B + C + D

$$\text{Sensitivity of case reporting} = A / (A + C)$$

$$\text{Predictive value positive (PVP)} = A / (A + B)$$

and agencies to participate in system (e.g., physician, laboratory, or hospital reporting rates).

Sensitivity. Case reporting sensitivity is defined as proportion of API cases detected by the surveillance system (Chart 1).

Predictive value positive. Proportion of persons identified as cases that really do have API (Chart 1).

Representativeness. Compare characteristics of reported API events with all such actual events. The total number of APIs in a given population is often not known but general descriptive information about the target population may be helpful: age, socioeconomic status, geographic location, and natural history of API (latency period, exposure route, and fatality or permanent disability outcome). In addition, a comparison of multiple data sources can identify types and degrees of underreporting. For example, comparing doctors' reports with those of poison control centers, laboratory records, hospital discharge records, or workers' compensation information might be helpful.

Timeliness. Can be assessed by determining time needed to complete each step within the API surveillance flow diagrams (Figure 1). Also important is the timeliness of the overall system. This can be evaluated by determining how quickly information is made available for API control and prevention efforts.

Resources Used to Operate System

What are the personnel needs, required equipment, and other operating costs?

Overall System Evaluation

Is the API surveillance system meeting its objectives and operating in an efficient and useful manner? Should any aspects of the system be modified?

ASSESSING THE RELATIONSHIP BETWEEN DISEASE AND AN OCCUPATIONAL OR ENVIRONMENTAL PESTICIDE EXPOSURE

API surveillance systems depend mostly on clinicians' reporting of cases, so it is critical for health care providers to accurately diagnoses pesticide-related health conditions, especially the more readily detected acute intoxications. Because pesticides are often associated with non-specific medical complaints (especially in the early stages of intoxication), it is very useful to link the traditional medical review of organ systems with an exposure history. Examples of interview questions for pediatric and adult exposure histories can be found in the text, Recognition and Management of Pesticide Poisonings.[5]

In evaluating the association of a given pesticide exposure in the occupational or general environmental setting and a clinical condition, key questions to consider include:

- Are the symptoms and physical signs appropriate for the pesticide being considered?
- Are there co-workers or others in the surrounding environment (e.g., farm, residence, school, neighborhood and non-farm workplace) who are ill?
- Do the timing of the exposure episode and the onset of health problems make sense?
- Is there confirmation of physical exposure to the pesticide (e.g., history of activity with direct pesticide contact, dermal residue sampling, proven pesticide contamination of work clothes or other personal protective equipment)?
- Is there any record of environmental monitoring data (e.g., crop residue, air, soil, or water pesticide tests)?
- Is there any record of biologic monitoring results?
- What is the biologic plausibility of the resulting health effect, given the exposure scenario?
- Can one rule out other non-pesticide exposures or pre-existing health problems?

A concurrent non-pesticide exposure can either have no effect on, exacerbate, or be the sole cause of the health condition under study. It is inappropriate to automatically eliminate occupational or environmental pesticide exposure as a possible contributory factor when underlying or concurrent non-pesticide exposures exist. Consultation with an occupational and environmental health specialist may be needed for those patients with complicated mixed-exposure scenarios or multiple concurrent disease situations.

INVESTIGATION OF A PESTICIDE INTOXICATION OUTBREAK

One important activity in an API surveillance system is to rapidly identify and investigate outbreaks or disease clusters. These investigations can be quite time-consuming and require a team approach with various health and safety professionals. Thus, a protocol is usually developed with action criteria for when a follow-up investigation should occur. Action criteria are further discussed in the section on API surveillance examples. The following outline covers the major steps involved in investigating an API outbreak:

1. Medical diagnosis
- Formulate a tentative medical diagnosis
- Confirm diagnosis of identified cases
- Review medical records (clinic, hospital, company)
- Review any biologic tests (e.g., cholinesterase activity, parent or metabolite levels)
- Review decontamination procedure for the patient, facility, and transport system
- Consult with treating health care providers
- All of these initial cases represent the group of "index cases"

2. Identify unrecognized cases
- Interview cases and other exposed individuals
- If feasible, interview non-exposed individuals as possible comparison group.
- Interview health care providers at clinics and hospitals in area of outbreak to detect any other cases
- If this is an occupational setting, then conduct interviews with co-workers, company management, and union representative (if unionized workforce). Also, interview company medical care provider and determine whether any medical monitoring exists for the pesticide-exposed workers.

3. API case definition
- Develop working case definition, which will include the following aspects: 1) exposure setting: pesticide type, population group, location and time period, 2) expected physical signs and symptoms, and 3) pertinent biologic or environmental tests.
- The Recognition and Management of Pesticide Poisonings text is a good resource for determining health effects of pesticides.[6]
- Table 1 contains an example of a case definition used for a recent pesticide intoxication outbreak in Central America.

4. Exposure information
- Evaluate the following outbreak information: pesticide formulations involved (concentration and physical form), timing and duration of exposure, delivery system, personal protective equipment used, weather conditions, and general circumstances of the exposure event.
- How many individuals were involved (include pesticide applicators/handlers and bystanders)
- Inspect any machine/apparatus used, original pesticide containers/labels, and personal protective equipment, if available.
- Review past pesticide application log, biologic monitoring records, and environmental sampling results (e.g., leaf or surface residue testing).

5. Characterize cases
- Create a line listing of index cases, additional cases, and exposed individuals. Table 2 illustrates the line listing created for the banana worker outbreak example.

6. Epidemic curve
- Plot out the incidence on a graph comparing number of individuals defined as number of cases versus time representing symptom onset.

TABLE 1 Example of a Case Definition Used in a Recent Pesticide-intoxication Outbreak

A case is defined as a farm worker who was present during a recent half-day application of a carbamate pesticide (Temik) at a banana plantation AND who has one or more symptoms consistent with cholinesterase inhibition (see table below). For those workers receiving medical attention, reversibility of symptoms after atropine treatment provides confirmation of cholinesterase inhibition.

Possible physical signs and symptoms associated with cholinesterase inhibiting pesticides (organophosphate and carbamate compounds).[6]

Category of Health Effect	Physical Signs and Symptoms
Early onset	Headache, nausea, dizziness, hypersecretion
More severe, later onset	Muscular twitch/fasciculations, weakness, tremor, incoordination, vomiting, abdominal cramps, diarrhea
Ocular	Miosis
Neuropsychiatric	Anxiety, restlessness, depression, memory loss, confusion, toxic psychosis
Respiratory	Bronchorrhea, bronchospasm, pulmonary edema, respiratory depression and arrest
Cardiovascular	Bradycardia and sinus arrest, tachycardia and hypertension, myocardiopathy
Advanced neurologic	Loss of consciousness, incontinence, convulsions

TABLE 2 Example of a Line Listing of Subjects for an Outbreak Investigation among Banana Workers Involved in Pesticide Applications*

Name	Age (years)	Job Title	Onset of Symptoms	Symptoms (Sx)	Treatment	Activity at Time of Exposure	PPE Use†
Worker 1	27	Backpack applicator	End of application	Dizzy, weak, diarrhea, vomiting	Atropine response, hospital x 1 day	Applying Temik	Yes
Worker 2	21	Backpack applicator	30 minutes after application ended	Severe headache	None	Applying Temik	Yes
Worker 3	31	Backpack applicator	Within 1 hour of end of application	Dizzy, weak, diarrhea, nausea, vomiting	Atropine response, hospital x 1 day	Applying Temik	Unknown
Worker 4	24	Backpack applicator	Within 1 hour of end of application	Dizzy, anorexia, abdominal pain, diarrhea	Atropine response, hospital x 1 day	Applying Temik	Unknown
Worker 5	Unknown	Backpack applicator	Within 1 hour of end of application	Nausea	Observed in ER for approx. 5 hours	Applying Temik	Unknown
Worker 6	Unknown	Backpack applicator	Within 1 hour of end of application	Nausea	Observed in ER for approx. 5 hours	Applying Temik	Unknown
Workers 7–15	Approx. 20–40	Backpack applicator	No sx reported	No sx reported	None reported	Applying Temik	Unknown

*All exposed workers were male and of Hispanic origin. Backpack application of Temik (a carbamate nematocide) occurred for approximately five hours partly during heavy rains.
†PPE = personal protective equipment used by worker, including boots, overalls, cartridge mask, and gloves.

- Figure 2 plots out the epidemic curve for the banana worker outbreak.

7. *Dose–response relationship*
- Determine severity of cases and compare with intensity of exposure. In this way, one can determine whether a dose–response relationship exists (cases with higher levels of exposure also have more severe clinical presentations). For the banana worker example, there was insufficient information about the individual pesticide exposure to allow a more detailed categorization of exposure level.

8. *Incidence rate*
- Derive an incidence rate for the outbreak: (Number of cases/Number of individuals exposed) × 100. In the case of the banana worker episode, the incidence rate is 40% ((6/15) × 100). Even if one accepts only cases that were reported by clinicians, the incidence rate is still quite high at 33.3% ((5/15) × 100).
- Finally, one can compare the outbreak incidence with the general population incidence and conduct a test for statistical significance to assess whether this elevated rate is likely to be real or due to chance.

9. *Report with recommendations for intervention*
- Summarize all the information gathered during the investigation in a report and present to all key stakeholders (e.g., workers, community residents, company representatives, medical community, governmental agencies).
- This report should clearly state the extent of the disease, the etiologic factors, and how to prevent or control the present exposure situation, as well as make recommendations for ways to prevent such episodes in the future.
- While all individuals evaluated should receive their personal test results, one needs to ensure that all public reports and communications with stakeholders maintain the confidentiality of the participants.

ACUTE PESTICIDE INTOXICATION SURVEILLANCE EXAMPLES—UNITED STATES

California Pesticide Illness Surveillance Program

California has required physician reporting of pesticide illnesses since 1971. Pesticide is defined as any substance that controls pests such as insects, fungi, weeds, rodents, nematodes, algae, viruses, bacteria, or adjuvants (substances added to enhance the efficacy of pesticides). Physicians are required to report any suspected case of pesticide-related illness or injury by telephone to the local health officer within 24 hours of examining the patient. Data sources for the Pesticide Illness Surveillance Program include: (1) the Pesticide
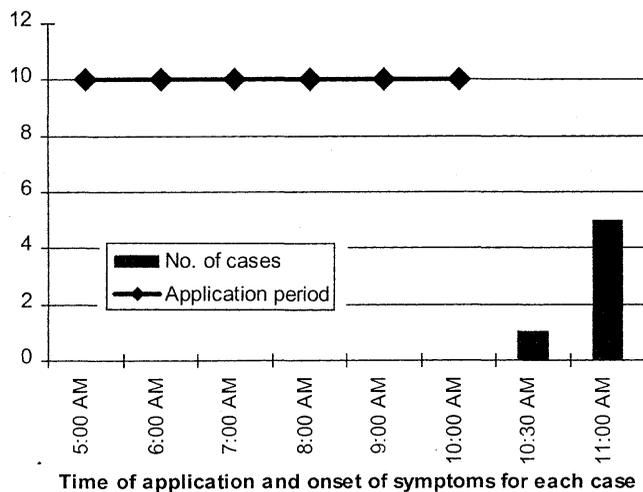
Figure 2—Epidemic curve for banana worker outbreak (6 cases/15 exposed workers).

Illness Report filled out by the health officer receiving the doctor's case report, (2) the Doctors' First Report of Occupational Illness and Injury, which is required for worker's compensation claims, and (3) the California Poison Control System, whereby poison control staff fill out a case report for physicians calling for assistance with a pesticide case.[7]

The county agricultural commissioner is responsible for the investigation of all pesticide-exposure incidents in his or her area. Specialized state-based laboratories provide analytic assistance for the pesticide-exposure investigations.[7] Criteria are used to indicate a high priority incident needing immediate attention: human health effects (death, hospitalized cases, or episode with five or more medically diagnosed illnesses), special incidents (involvement of neighboring states or Mexico), environmental effects (special air, water, animal, and land contamination scenarios), and property loss or damage (depending on extent of financial loss). Yearly summary reports highlight important investigative findings.

Table 3 illustrates results from three years of API surveillance, 1997 through 1999. There were 4,916 cases evaluated as being pesticide-related, with 80 (2.3%) hospitalizations and seven (0.2%) deaths. The majority of the cases presented with systemic symptoms (64%) and involved occupational exposures (82%). Two of the most common activities at the time of exposure were pesticide application (23%) and field work (15%). For agricultural cases, the individuals tend to be predominantly male and younger in age than other cases (Figure 3). For the period 1982–1998, the most common pesticides involved in occupational episodes were sodium hypochlorite, chlorine, and chlorpyrifos (for systemic effects), and sodium hypochlorite, quaternary ammonia, and propargite (for eye and dermal effects) (Table 4). The non-occupational cases had metam-sodium as the most common pesticide exposure, partly due to a large environmental outbreak.

TABLE 3 Selected Data from the California Pesticide Illness Surveillance Program for the Three-year Period 1997–1999[7-9]

	1997	1998	1999	1997–1999 Period
Total reports received	1,806	1,481	1,629	4,916
Pesticide-related cases*	1,319	998	1,201	3,518 (72% of all reports)
Category of cases*				
Definite	261	216	195	672 (19%)
Probable	631	405	635	1,671 (48%)
Possible	427	377	371	1,175 (33%)
Hospitalizations	20	26	34	80 (2.3%)
Fatalities	1	2	4	7 (0.2%)
Health effects of cases				
Systemic	815	574	851	2,240 (64%)
Eye	247	229	191	667 (19%)
Skin	220	177	141	538 (15%)
Eye and skin	37	18	18	73 (2%)
Circumstances of exposure				
Agricultural exposure	545	366	555	1,466 (42%)
Occupational setting	1,158	914	804	2,876 (82%)
Selected activities at time of exposure				
Mixing/loading pesticides	115	84	67	266 (8%)
Pesticide application	328	281	200	809 (23%)
Field work	208	170	134	512 (15%)
Commodity packing/processing	25	33	92	150 (4%)

*Pesticide-related indicates that the relationship between pesticide exposure and resulting symptoms was one of the following:

Definite—High degree of correlation with both medical evidence (e.g,. cholinesterase inhibition, positive allergy test, signs observed by clinician) and physical evidence of exposure (e.g., environmental or biological samples and exposure history).
Probable—Relatively high degree of correlation, with either medical or physical evidence being inconclusive or unavailable.
Possible—Some degree of correlation with both medical and physical evidence inconclusive or unavailable.
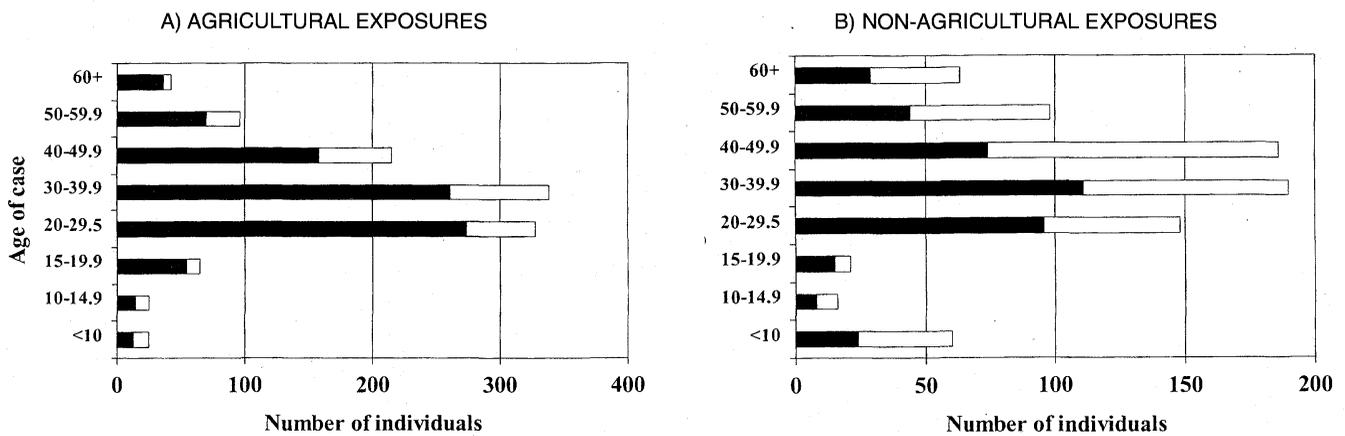
Figure 3—Age and gender (black bars = male; white bars = female) distribution of cases related to pesticide exposures other than antimicrobials, California Pesticide Illness Surveillance Program, 1997–1999. Total of 3,200 cases represented (318 missing age, gender, or agricultural status information).[7-9]

All of the cases showing the following types of strength of relationship between pesticide exposure and resulting symptoms are included: **definite**—*high degree of correlation with both medical evidence (e.g., cholinesterase inhibition, positive allergy test, signs observed by clinician) and physical evidence of exposure (e.g., environmental or biological samples and exposure history);* **probable**—*relatively high degree of correlation, with either medical or physical evidence being inconclusive or unavailable; and* **possible**—*some degree of correlation with both medical and physical evidence inconclusive or unavailable.*

Due to the extensive nature and long duration of this surveillance system, the API database has been used extensively in health policy development, rule making, research, risk assessment, intervention programs, and evaluation efforts. Several problems exist which may potentially cause underreporting of certain API cases: lack of physician recognition of APIs; subtle and early manifestations of API may not cause an individual to seek medical care; some residents or workers lack medical insurance and do not seek medical care until severe symptoms develop; some residents or workers lack residency documents and do not feel empowered to complain about health problems or seek medical care; some individuals are binational and receive medical attention in their native country (e.g., Mexico); and the migratory nature of some individuals do not allow follow-up or continuity of medical care that would help the medical diagnosis of more subtle or chronic disease. With respect to the surveillance system, some question the strictness of the case definition that may discard some cases that may be true APIs. Language and cultural barriers at the employer, medical community, and surveillance staff levels may pose a problem in light of the diverse population in California (especially among high-risk groups), and some of the non-priority investigations take a long time to be conducted and may compromise the data collection.

SENSOR–Pesticides Program

The Sentinel Event Notification System for Occupational Risk (SENSOR) is a program administered by NIOSH to build and maintain occupational illness and injury surveillance capacity within state health depart-

ments. The SENSOR-Pesticides program has a focus on API and includes the state heath departments of the following states: California (this program is different from the California Department of Pesticide Regulation program described in the prior section), New York, Texas, Florida, Oregon, New Mexico, and Washington). The first three state programs are co-funded by NIOSH and EPA, Florida and Oregon are funded solely by NIOSH, and the last two states have self-funded programs but are considered partners in the overall SENSOR–Pesticides program. The goals of SENSOR-Pesticides include: 1) tabulation of API cases, 2) in-depth investigations for case confirmation, 3) development of intervention programs at selected industries or for certain pesticide hazards, 4) timely identification of outbreaks and emerging pesticide problems, and 5) development of a national aggregated API data base.[11]

The reporting sources for SENSOR include physicians' reports, hospital discharge records, poison control center data, laboratory reports (cholinesterase tests), mortality data, and worker's compensation records. The SENSOR–Pesticides program has developed various surveillance-related products for use by participating states: standardized pesticide-related illness case definition, list of standardized reporting variables, and database software (entitled SPIDER) to collect a core set of variables on each case. Table 5 contains the yearly incidence data for the SENSOR state programs. It is interesting to compare the 1998 data from the California SENSOR and California Pesticide Illness Surveillance Programs. The SENSOR program identified 289 occupational pesticide-related cases (definite, probable, and possible classification), while the latter program had 914 cases (also with definite, probable,

and possible designations but interpreted differently). The California Pesticide Illness Surveillance Program detected over three times as many API cases due partly to a different case definition and classification but this could also be related to this system's more extensive surveillance infrastructure with the ability to conduct investigations on nearly every case report. On the other hand, since all SENSOR states use identical case definitions and classifications, the possibility of combining results across several states is very promising.

ACUTE PESTICIDE INTOXICATION SURVEILLANCE EXAMPLES—INTERNATIONAL

WHO Acute Pesticide Intoxication Data Collection

A simple format for collection of data on acute pesticide intoxication has been developed by the International Program on Chemical Safety, World Health Organization.[12] To develop the survey instrument and a guidance document, workshops on harmonization of data collection on pesticide intoxications were held with key stakeholders. Furthermore, field testing of the survey instrument in selected countries was conducted. Currently, harmonized case data collection using the proposed method is conducted in selected regions of countries in Southeast Asia and the Western Pacific Region. The overall objective of this project is to estimate the extent of human pesticide exposure and poisoning in selected regions/countries with a view to implement preventive and education strategies to reduce morbidity and mortality from pesticide poisoning.

The guidance document for the project participants includes information about objectives, study design, coordination, implementation, and budget considerations. The main sections of the one-page pesticide-

TABLE 4 List of Pesticides Associated with at Least 100 API Cases Identified by the California Pesticide Illness Surveillance Program, 1982–1998.

	Systemic		Eye/Skin		
	Definite/Probable	Possible	Definite/Probable	Possible	Total
In occupational settings					
Sodium hypochlorite	847	243	1711	215	3,016
Sulfur	118	114	326	492	1,050
Quaternary ammonia	46	30	717	64	857
Chlorine	531	99	98	75	803
Chlorpyrifos	341	289	113	44	787
Propargite	19	20	490	150	679
Glyphosate	32	76	354	152	614
Diazinon	188	167	65	29	449
Malathion	187	104	40	18	349
Glutaradehyde	87	22	205	17	331
Propetamphos	156	82	8	4	250
Cyanuric acid	68	13	142	23	246
Methyl bromide	66	55	86	10	217
Metam-sodium	103	20	71	18	212
Methomyl	94	69	20	22	205
Phenolic disinfectants	15	10	153	16	194
Aluminum phosphide	100	47	6	28	181
Calcium hypochlorite	71	19	69	10	169
Parathion	75	69	9	5	158
Mevinphos	4	68	10	5	157
Cyfluthrin	89	28	11	16	144
Dimethoate	78	35	17	10	140
Propoxur	55	46	28	8	137
Creosote	8	2	82	27	119
Paraquat	15	25	59	13	112
In non-occupational setting					
Metam-sodium	341	83	54	2	480
Diazinon	73	39	4	10	126
Chlorpyrifos	57	60	3	1	121
Malathion	87	22	9	1	119
Chlorine	94	12	8	0	114

*These cases were determined to be definitely, probably, or possibly related to pesticide exposure.[10] Strength of relationship between pesticide exposure and resulting symptoms:

Definite—High degree of correlation with both medical evidence (e.g., cholinesterase inhibition, positive allergy test, signs observed by clinician) and physical evidence of exposure (e.g., environmental or biological samples and exposure history).
Probable—Relatively high degree of correlation with either medical or physical evidence being inconclusive or unavailable.
Possible—Some degree of correlation, with both medical and physical evidence inconclusive or unavailable.

TABLE 5 Occupational Acute Pesticide Intoxication (API) Cases Reported by Each SENSOR State*

Case Classification†	Arizona‡	California	Florida	New York	Oregon	Texas	Total (% of all cases)
Definite	1	16	67	7	0	12	103 (14%)
Probable	6	138	22	5	2	7	180 (25%)
Possible	15	135	79	3	25	135	392 (53%)
Suspicious	0	53	3	1	13	0	60 (8%)
Total	22	342	171	16	30	154	735

*Figures represent 1999 data except for California with 1998 data.[11]
†Case definition: an acute onset of symptoms dependent on the formulation of the pesticide product and involving one or more systemic symptoms or signs, dermatologic effects, and ocular effects. If available, laboratory data may confirm diagnosis of API. Furthermore, a case is reportable to the national surveillance system when there is documentation of two or more new adverse health effects that are temporally related to a documented pesticide exposure *and* consistent evidence of a causal relationship between the pesticide and the health effects based on the known toxicology of the pesticide. The case classification is complex and depends on the extent of exposure, health effects, and causal relationship.
‡API surveillance in this state was self-funded.

exposure record include information about exposure time and place, source of information, patient details, circumstances of exposure, main activity at time of exposure, location of exposure, route of exposure, product identity, chemical type, medical management, severity rating, clinical outcome and final overall comments. The poisoning severity score is derived from an extensive matrix that looks at type of organ system involvement (gastrointestinal, respiratory, nervous, cardiovascular, hepatic, renal, hematologic, dermal, ocular, and muscular) to then provide a score of 0 (none = no symptoms or signs), 1 (minor = mild, transient, and spontaneously resolving symptoms or signs), 2 (moderate = pronounced or prolonged symptoms or signs), and 3 (severe = severe or life-threatening symptoms or signs). An adaptation of this pesticide exposure record was used for a recent nationwide survey of acute pesticide intoxications in Belize and proved to be quite useful in obtaining key information in a standardized way from medical records and health care providers.

Belize—PLAGSALUD Project

Belize is one of seven countries participating in the Occupational and Environmental Aspects of Exposure to Pesticides in the Central American Isthmus project (PLAGSALUD). This program is funded by the Danish International Development Agency (DANIDA) under the technical execution of the Pan American Health Organization (PAHO)/World Health Organization (WHO). PLAGSALUD programs are carried out in conjunction with the health ministries and other related governmental and nongovernmental organizations within the respective countries. In 1994, Nicaragua and Costa Rica were the first countries to participate in PLAGSALUD. An expansion of the program to the remaining Central American countries occurred in 1997: Belize, Panama, Guatemala, Honduras, and El Salvador were added.

The goal is to implement surveillance systems for detection of APIs and strengthen national capacity to respond to pesticide problems. Recently, the author was involved in a survey to estimate the overall prevalence of APIs and to determine the degree of case underreporting for the two highly agricultural districts where surveillance occurs. Belize has 240,000 residents, with approximately 21,400 persons (9% of the population) involved in agricultural activities. The country is highly agricultural, with this industry contributing 15% of the gross domestic product. The API surveillance system has been operational in Cayo and Stann Creek Districts since 1999. In 2000, there were 22 API cases, including two fatalities (annual incidence rate of 2.9 cases/10,000 residents). In June 2001, a questionnaire survey of the country was conducted with sampling from three pesticide-exposure risk strata: high (vector control and quarantine officers, farm workers, farmers, pest-control workers, pesticide handlers and applicators); medium (rural residents living close to agricultural activity); and low (remaining rural residents and urban dwellers). The standardized interview asked about demographic data, current work and home characteristics, exposure to pesticides, and any associated symptoms, medical visits, or hospitalizations. A total of 1,059 questionnaires were completed: 294 high-, 441 medium-, and 324 low-risk individuals. In addition, API records from the major hospitals and clinics were obtained using an adaptation of the WHO pesticide exposure record form. Data analysis is currently under way to derive estimated national and regional incidence rates for API, as well as to compare API cases identified from the surveillance system, clinical/hospital records, and the questionnaire survey. Recommendations will be made for improvement of the API surveillance system, intervention measures, and usefulness of this model for other countries in Central America.

South Africa—Evaluation of Pesticide Poisoning Surveillance

A recent example of an API surveillance evaluation was conducted for the system in the Western Cape Province

of South Africa.[13] In South Africa, pesticide intoxication has become a major public health problem as increasing usage of pesticides has occurred in the last decade. The pesticide poisoning surveillance system in South Africa relies primarily on reports from health care practitioners (mandatory notification), the Department of Labor (occupational cases), and the Department of Home Affairs (death certificate information). Furthermore, local environmental health officers are responsible for follow-up investigations and remediation. On average, from 100 to 200 cases of human pesticide poisoning are reported annually, with 10–20 of these being fatal. By conducting an intensive survey and intervention project in the Western Cape Province, the researchers were able to compare the results from this project with those of the routine surveillance system. The community-based project provided free cholinesterase testing, information, training, and educational materials to local health care providers.

The findings during this intensive survey included: a nearly tenfold increase in case reporting (40.5 cases/100,000 residents for the year of the project versus 4.2/100,000 average for the prior five-year period), doubling of female cases (61% female for intensive survey versus 30% for routine provincial surveillance data), increased occupational cases (86% intensive data versus 12% routine data), and decreased suicide cases (9% intensive data versus 35% for routine data). The intensive survey suggests that there is an API underreporting rate of 90% for the routine surveillance system. Furthermore, many of the exposure situations detected by the intensive survey indicated circumstances of normal use or involving factors that were beyond the control of the index case. Conversely, the Health Department has stated that in local studies derived from surveillance reporting, the main cause of pesticide poisoning is ignorance. Suggestions for improving the routine system include: collecting appropriate data that are linked to intervention activities, better effort to understand the exposure circumstances of the cases and avoid the tendency to blame the case for all exposure incidents, and better cooperation between the different reporting sources and the participating governmental and nongovernmental groups..

Nicaragua—Underreporting of Pesticide Intoxications

To determine the true extent of pesticide intoxication and the degree of underreporting of the existing surveillance system, an agricultural area (grain, cotton, and cattle) was studied during the period of heavy pesticide use.[14] In 1988, a survey was conducted at agricultural cooperatives and nearby private farms that were convenient to a regional health center. A short standardized questionnaire was administered to agricultural workers asking whether the individual had ever been made ill due to pesticides, and if yes, what were

the location, date, symptoms, and other circumstances associated with the incident. If three of the following symptoms commonly seen in cholinesterase inhibition were reported, then the individual became a verified API case: lightheadedness, blurred vision, nausea, vomiting, weakness, excessive sweating, tremor, excessive salivation, headache, difficulty breathing, convulsions, and loss of consciousness. In addition, the number of cases identified by the questionnaire survey were compared to the cases reported with the regional pesticide poisoning registry.

Of the 633 interviews conducted, there was no refusal during study recruitment at the 25 agricultural cooperatives in the study area. There were 520 persons (82%) reporting pesticide use and 158 (25%) reporting a pesticide-related illness during the prior 12 months. Among the 304 persons (48% of total study group) reporting at least one lifetime poisoning or illness due to pesticides, 225 (74%) were verified cases as per the study definition. The names of the medically treated cases were compared with the API registry list, with only eight of 23 cases being identified. Thus, an estimated underreporting rate of 65% was derived. The representativeness of the study population may be in question due to using only agricultural workers and not employing a stratified random sample of the population. Furthermore, the broad case definition with the focus on the acute symptoms of cholinesterase-inhibiting pesticides may lead to an inaccurate overall API rate. Nonetheless, there is still a very large rate of cases that are not being detected by the existing surveillance system due to ill people's not seeking medical attention (24 of 47 total ill, or 51%), and cases that were treated but not reported (15 of 47, or 32%).

MEDICAL MONITORING OF WORKERS EXPOSED TO PESTICIDES

In California, state law requires that medical supervision be established for a particular group of pesticide-exposure workers. An employer is required to provide medical supervision for workers that regularly handle an organophosphate or carbamate pesticide with "Danger" or "Warning" on the label.[15] Regular handling is defined as mixing, loading, or applying the pesticide for more than six days in any 30 day period. These pesticides act through the inhibition of the enzyme cholinesterase and can produce a wide variety of health effects (Table 1). Once a medical supervisor is selected, several components are required to be in place to fully implement a medical monitoring program (Table 6).

The described program constitutes the bare minimum needed for compliance with a regulation. The general principles of a surveillance system and good medical practice need to be kept in mind. For example, one may choose to include field workers who poten-

TABLE 6 Medical Supervision for Workers Exposed to Cholinesterase Inhibitors*

Program Element	Action Required
Medical supervisor	Employer contracts with licensed physician to become Medical Supervisor of program
Cholinesterase (ChE) testing	Obtain erythrocyte (RBC) and plasma ChE levels; because of variability between laboratories, use the same laboratory for all ChE testing
Baseline ChE level	Taken when worker has not been exposed to organophosphates or carbamates for 30 days
New employee testing	Test at end of each of the first three 30-day periods of regular handling; then, do periodic testing every 60 days or as recommended by the medical supervisor

Action criteria for ChE levels:
   ChE drops 20% below baseline level
   RBC ChE drops 30% or lower
   Plasma ChE drops 40% or lower
	
	Employer must evaluate workplace and correct any unsafe situations
	Exposure to organophosphates or carbamates must stop
	Exposure to organophosphates or carbamates must stop

Criteria for resuming work with potential organophosphate or carbamate exposure	Both RBC and plasma ChE levels return to at least 20% of baseline

*This program is based on the California Code of Regulations, Title 3, and is required of employers with workers who handle cholinesterase or carbamate pesticides.[15]

tially get secondary, bystander, or unintentional direct exposures, one would want to assess other chemical and physical agents that might pose hazards and exacerbate any health problems, there should be integration of this medical supervision with any medical evaluation for respirator use, emergency response and decontamination procedures, and worker or management safety and health training. Furthermore, the surveillance principles of ongoing standardized data collection, analysis, interpretation, dissemination and follow-up intervention need to be considered. For a medical supervision program these items translate into collection of all pertinent health and exposure data, analysis not only of an individual response but also of the entire work group to identify any trends (e.g. use of epidemic curve), interpretation of any changes in biological measurements in conjunction with workplace and personal medical factors, routine reporting of findings to both the workers and management (with appropriate attention to confidentiality issues), and possible in-depth outbreak investigations, as needed.

PESTICIDE EXPOSURE MONITORING

California Pesticide Use Data

An example of a pesticide-exposure surveillance system is that found in California. Since 1990, the state has required the reporting of all agricultural pesticide use.[9] Each year, 45,000 to 50,000 operator identifications for pesticide use are issued in California, representing 185,000 to 200,000 fields or sites. There are approximately 2.5 million pesticide products applied to agricultural fields. The data collection involves site identi-

fication numbers, commodity treated, planted and treated acreage, pesticide(s) used, amount applied, application method, time and date of application, and township or section of state where activity occurred. The types of pesticide uses reported include agriculture production, postharvest commodity treatment, structural fumigation, landscape maintenance and all other reported agricultural uses. The mandatory reporting does not apply to home and garden use and most industrial and institutional uses. Figure 4 shows the gradual increase of agricultural pesticide use reported over the period 1991 through 1998. Annual statewide summaries of pesticide use categorized by chemicals and crops are available online. These online data have been used for risk assessment, evaluation of regulatory action, and research purposes.

National Report on Human Exposure to Environmental Chemicals

The National Center for Environmental Health, Centers for Disease Control, has recently issued a report on a project that will conduct a more precise type of exposure assessment by conducting biologic monitoring of selected toxicants for the general population.[16] The National Report on Human Exposure to Environmental Chemicals provides the first of an ongoing assessment of the U.S. population exposure to 27 chemicals, including organophosphate pesticide metabolites in the urine. The urine samples are from the 1999 National Health Nutrition and Examination Survey (NHANES), which is a continuous national sample of the U.S. population. NHANES conducts a standardized health interview, physical examination, and testing of biologic fluids. The
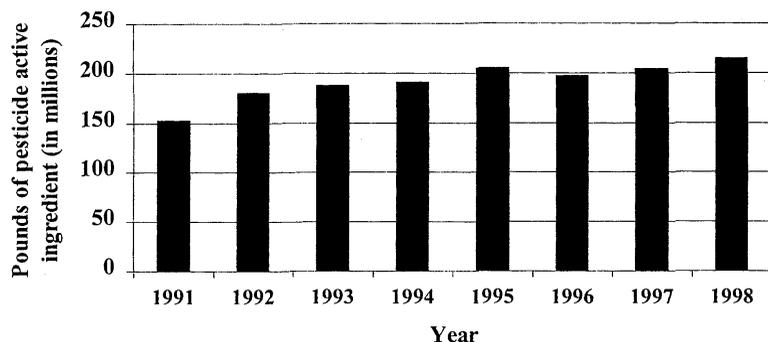
Figure 4—Total amounts of reported pesticide use as pounds of active ingredient.[9]

goal is to issue annual updates that will combine the analysis results with those of other large exposure studies within the United States. The first preliminary results include the following organophosphate urinary metabolites: dimethylphosphate (DMP), dimethylthiophosphate (DMTP), dimethyldithiophosphate (DMDTP), diethylphosphate (DEP), diethylthiophosphate (DETP), and diethyldithiophosphate (DEDTP) (Table 7). These six metabolites are non-pecific breakdown products of a wide variety of organophosphate pesticides including chloryrifos, diazinon, fenthion, malathion, parathion, phosmet, temephos and methyl parathion. This type of pesticide exposure trend data (especially when paired with the NHANES health information) promises to be a more precise assessment of body burden than the usual measurement of external pesticide use.

INFORMATION SOURCES

The following are sources that provide information about pesticide exposures, health effects, and surveillance systems (both exposure- and disease-based):

Recognition and Management of Pesticide Poisonings, 5th Edition, 1999
This book provides diagnostic and medical management information for acute pesticide intoxications (for all EPA-registered and noteworthy non-registered pesticides). This manual can be ordered in English or Spanish by calling the Office of Pesticide Programs, US EPA, at (703) 305-7666 or via Web site <www.epa.gov/pesticides/safety/healthcare>. At this site, one can also access the manual in electronic format.

National Pesticide Telecommunications Network (NPTN)
<http://ace.orst.edu/info/nptn/>
NTPN is based at the Oregon State University and is cooperatively sponsored by the University and the U.S. EPA. This network provides information about pesticide poisonings, handling information, environmental and occupational health effects, referrals for investigations of pesticide incidents, emergency treatment for humans and animals, and cleanup and disposal procedures. The telephone hotline and e-mail query serve the United States and its territories: (800) 858-7378

TABLE 7 Distribution of the Organophosphate Urinary Metabolites as Geometric Mean (GM) and Percentile Levels for the U.S. Population, Aged 6–59 Years, NHANES Data, 1999*

N = 703	GM (95% CI)	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
DMP	1.84[1] (1.10–2.59)	< LOD[2]	0.49	1.56	4.02	10.1
DMTP	2.61[1] (1.77–3.45)	< LOD[3]	0.59	3.08	7.87	23.6
DMDTP	0.51[1] (0.39–0.62)	< LOD[4]	< LOD[4]	0.42	1.57	5.33
DEP	2.24 (1.11–3.37)	0.43	0.81	1.87	5.85	12.13
DETP	0.71 (0.56–0.87)	0.26	0.38	0.64	1.25	2.32
DEDTP	0.16 (0.12–0.21)	0.04	0.07	0.14	0.33	0.70

*See text for explanation of metabolite abbreviations. Sample size for all metabolite categories was 703 individuals. Units for metabolite levels are microgram per gram creatinine in urine except where elsewhere noted.
[1]Unit is µg/L urine.
[2]Limit of detection is 0.51 µg/L urine.
[3]Limit of detection is 0.18 µg/L urine.
[4]Limit of detection is 0.08 µg/L urine.

(9:30 AM–7:30 PM EST daily except for holidays), and <nptn@ace.orst.edu>. Pesticide-related information and links to other online informational sources can be found at the Web site.

Association of Occupational and Environmental Clinics (AOEC)
<http://152.3.65.120/oem.htm>
This association is a network of over 60 clinics representing more than 250 specialists. Their Web site is very useful for general medical information and links to other sites dealing with all types of occupational and environmental health issues (including pesticide exposures).

Extension Toxicology Network (EXTOXNET)
<http://ace.ace.orst.edu/info/extoxnet>
EXTOXNET provides toxicologic information about pesticide-related health effects and is maintained as a cooperative effort by the University of California–Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho.

Integrated Risk Information System (IRIS)
<http:/ace.ace.orst.edu/info/extoxnet>
IRIS is an electronic database maintained by the U.S. EPA that deals with human health effects resulting from exposures to various chemicals in the environment. IRIS is intended for those persons without extensive training in toxicology but with some knowledge of the health sciences. Information is provided on hazard identification and dose–response assessment, with extensive supporting documentation available online.

Agency for Toxic Substances and Disease Registry (ATSDR)
<http://atsdr1.atsdr.cdc.gov:8080/toxfaq.html>
ATSDR publishes fact sheets and other information about pesticides and other toxic substances.

California Pesticide Data Bases
<www.cdpr.ca.gov/docs/database/database.htm>
This Web site includes Pesticide Chemical Ingredients Queries, links to the U.S. EPA Office of Pesticide Programs chemical dictionary, Pesticide Product and Label Data Base Queries (updated nightly), access to reports from the California Pesticide Illness Surveillance Program, and the Pesticide Use Report Data.

Note added in proof: Since the writing of this article, two new resources have become available: 1) SENSOR Web site, www.cdc.gov/niosh/potsurv and 2) Updated guidelines for evaluating public health surveillance systems, MMWR. 2001; 50, July 27, no. RR-13.

References

1. National Institute for Occupational Safety and Health. Tracking Occupational Injuries, Illnesses and Hazards: The NIOSH Surveillance Strategic Plan. DHHS (NIOSH) Pub. No. 2001-118, Washington, DC: NIOSH, January 2001.
2. International Labor Organization. Technical and Ethical Guidelines for Workers' Health Surveillance. Geneva, Switzerland: ILO, 2–9 September 1997.
3. Klauke DN, Buehler JW, Thacker SB, et al. Guidelines for evaluating surveillance systems. MMWR. 1988; 37(S-5):1-18.
4. Centers for Disease Control and Prevention. Framework for program evaluation in public health. MMWR. 1999; 48(RR-11): 1-40.
5. Osorio AM. Environmental and occupational history. In: Reigert JR, Roberts JR (eds). Recognition and Management of Pesticide Poisonings, 5th ed. EPA 735-R-98-003. Washington, DC: EPA, March 1999: 17-32.
6. Reigert JR, Roberts JR. Recognition and Management of Pesticide Poisonings. 5th ed. EPA Pub. No. 735-R-98-003. Washington, DC: EPA, March 1999.
7. Department of Pesticide Regulation. Summary of Results from the California Pesticide Illness Surveillance Program, 1999. DPR, California Environmental Protection Agency, Pub. No. HS-1811, Sacramento, CA, February 2001.
8. Department of Pesticide Regulation. Overview of the California Pesticide Illness Surveillance Program, 1997. DPR, California Environmental Protection Agency, Pub. No. HS-1783, Sacramento, CA, February 2000.
9. Department of Pesticide Regulation. Summary of Results from the California Pesticide Illness Surveillance Program, 1998. DPR, California Environmental Protection Agency, Pub. No. HS-1795, Sacramento, CA, February 2000.
10. Mehler L. Personal communication, Worker Health and Safety Branch, Department of Pesticide Regulation, Sacramento, CA, October 2000.
11. National Institute for Occupational Safety and Health. SENSOR Pesticides Annual Report, Fiscal Year 2000. Washington DC: NIOSH, February 2001.
12. International Program on Chemical Safety, United Nations Environment Program, International Labor Organization and World Health Organization. Report of the IPCS Regional Workshop on Epidemiology of Pesticide Poisoning: Harmonized Collection of Data on Human Pesticide Exposures in Selected Countries of the Western Pacific Region. IPCS/WHO, Singapore, December 1999.
13. London L, Bailie R. Challenges for improving surveillance for pesticide poisoning: policy implications for developing countries. Int J Epidemiol. 2001; 30:564-70.
14. Keifer M, McConnell R, Pacheco AF, Daniel W, Rosenstock L. Estimating underreported pesticide poisonings in Nicaragua. Am J Ind Med. 1996; 30:195-201.
15. Department of Pesticide Regulation. Medical Supervision, Pesticide Safety Information Series A. DPR, California Environmental Protection Agency, Pub. No. HS-8, Sacramento, CA, September 1998.
16. Centers for Disease Control and Prevention. National Report on Human Exposure to Environmental Chemicals. Center for Environmental Health, CDC, <www.cdc.gov/nceh/dls/report>, 21 March 2001.
17. Department of Pesticide Regulation. Summary of Pesticide Use Report Data: 1995, 1996, 1997.