WATER QUALITY: PREVENTING OFFSITE PESTICIDE RESIDUE MOVEMENT IN ALFALFA

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All growers farm under the requirement not to pollute surface and ground water. Water leaving the field, irrigation runoff or winter storm water, can contain residues of applied pesticides, sediment or nutrients. These surface discharges are regulated by the Central Valley Regional Water Quality Control Board under a program called the Irrigated Lands Program. Essentially, the Board is now enforcing non-point source laws that have been on the books since 1969. In mid 2003, the Regional Board adopted two conditional waivers for discharges from irrigated lands. One was for coalition groups that form on behalf of individual dischargers to comply with California Water Code and Regional Water Board plans and policies. Today there are about ten coalition groups representing geographic areas or specific commodities. The other conditional waiver was for growers who wanted to comply as individual entities with California Water Code and Regional Water Board plans and policies.

Under the Irrigated Lands Program, the Water Quality Coalitions must:

- Comply with all water quality triggers as established in the Basin Plan
- Monitor watersheds to demonstrate compliance
- Develop Management Plans in areas where water quality triggers are exceeded—called exceedances.

Determination of Exceedances

- Based on water quality triggers developed by the State and Regional Water Quality Control Board and US EPA
- Established to protect beneficial uses of all upstream tributaries

Monitoring. The Water Quality Coalitions were tasked with monitoring waters within their coalition area for test organism toxicity and the presence of a hold host of nutrients, sediments and pesticides. Beginning in 2004 and continuing today, the coalitions have found many exceedances of water quality standards. Test organisms are used to determine the presence of some toxic compound.

Toxicity Tests

- *Pimephales promelas* (Minnow)
- *Ceriodaphnia dubia* (water flea)
- *Selenastrum* (algae)
- *Hyalella azteca* (sediment)

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Other tests include analysis for:

- metals
- nutrients
- salinity (TDS and conductivity)
- pathogen Indicators (Fecal coliform and *E.coli*)
- pesticides

Exceedances have occurred in all Coalition areaS within Region 5. Figure 1 shows the total number of samples collected by the Coalitions within Region 5 and the number of exceedances by test species. Each test species is a greater or lesser sensitivity to a specific class of pesticide. The percent of total tests that resulted in exceedances is shown in Figure 2. Algae and sediment exceedances are greater than those of the minnow and water flea. The bulk of the sediment toxicities were caused by Pyrethroids and Chlorpyrifos or a combination of the two—all important pesticides used in the culture of alfalfa.

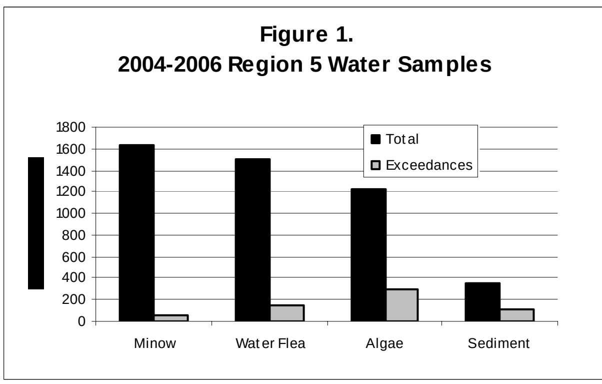


Figure 1.
2004-2006 Region 5 Water Samples

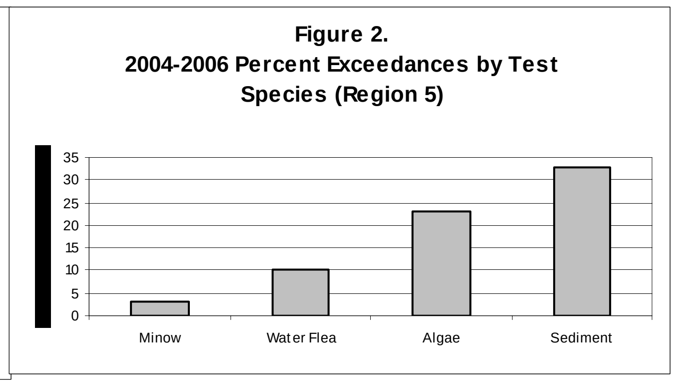
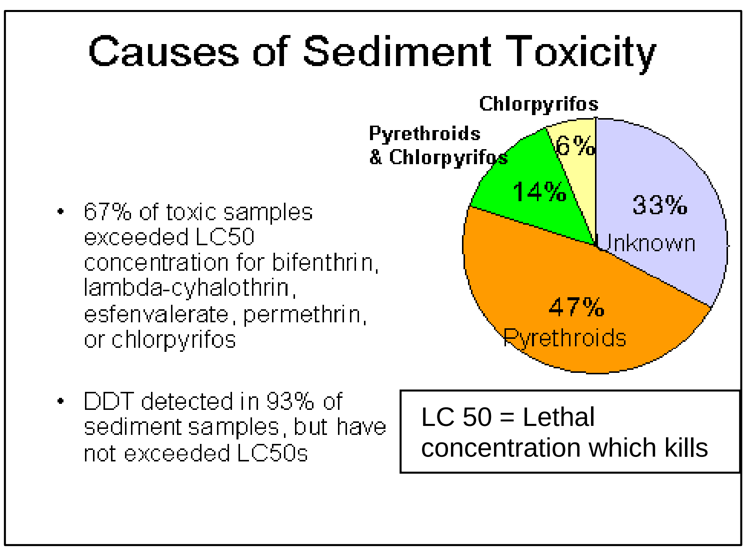


Figure 2.
2004-2006 Percent Exceedances by Test Species (Region 5)

Figure 3.



The time of year exceedances occur is important in determining the type of applications which may be causing the exceedances. Table 1 shows a typical exceedance report noting the date and chemical responsible. Using this information for a specific watershed, exceedances can be correlated with the Pesticide Use Reports indicating the site, grower and crop which may need to improve management practices to prevent exceedances.

Table 1. Pesticides, metals, salts (TDS) and E. coli exceedances

Sample Date	Chlorpyrifos (Lorsban) (µg/L)	Color (color units)	Cyhalothrin, lambda (µg/L)	Cypermethrin (µg/L)	Diazinon µg/L	E. coli (MPN/100 mL)	Total Dissolved Solids (mg/L)	Thiobencarb (µg/L)	DDE (µg/L)
9/20/05		150				1600			
2/27/06	0.018	1000				1600	730		
3/15/06		500				1600			
8/24/04		50				500			
9/23/04		50							
2/16/05		800			0.089	1600			
3/21/05		150				900			
5/17/05		50				900			
6/21/05		75				500			
7/19/05	0.036	60	0.006	0.03		900			
8/16/05	0.019	75							
8/16/05	0.019	75				500			
9/20/05		80				1600			
2/27/06		300				900			
3/15/06		750				1600			
7/18/06	0.019								
6/20/06								0.004	0.12
7/18/06	0.031								

To further indicate the pesticides which cause the most exceedances, Table 2 shows the results from the 2007 storm samples (2 at each of the 16 sites) and irrigation season samples (8 at each site of the 16 sites). Sediment sample results were not available at this time. For the storm season, 44% of the samples had exceedances while irrigation exceedances were 19%. Of the exceedances, 62% were chlorpyrifos and 19% were diazinon. Table 3 is provided to compare these exceedance results with the insecticides commonly used in alfalfa production. The potential for solution runoff, adsorption runoff and overall risk is presented for each insecticide. Using this chart, growers can use materials which have less potential for off-site movement when conditions indicate movement is likely.

Table 2.

	Pesticide Exceedances 2007 *												
	Carbofuron	Chlorpyrifos	Cypermethrin	Diazinon	Dieldrin	Disulfoton	Diuron	Malathion	Methidathion	Simazine	Thiobencarb	Samples with > 1 Exceedance	Estimated Sample Number	% of samples with > one Exceedances
Limits	0 µg/L	0.015 µg/L	0.002 µg/L	0.1 µg/L	0.00014 µg/L	0.05 µg/L	2 µg/L	0 µg/L	0.7 µg/L	4.0 µg/L	0 µg/L	Total		
April - September 6 Irrigation Samples	1	9	1		1	1					2	15	80	19
Feburary 2 Storm Samples		7		5			2	1	2	2		11 **	25	44
Pesticide as % of Total Samples	1.0	15.2	1.0	4.8	1.0	1.0	1.9	1.0	1.9	1.9	1.9			
Pesticide as % of Exceedances	4	62	4	19	4	4	8	4	8	8	8			

* The above table contains preliminary water quality monitoring results from the 2007 storm water and irrigation season and as such is subject to quality control review. Percentages are based on an estimate of total sample number. Final results will be available by December 31 in the semi-annual coalition report to the Regional Water Quality Board.

** Note: Some samples have more than one pesticide exceedance (19 total exceedances in 11 samples with exceedances).

Table 3. California-registered insecticides ranked by potential to move in solution or as adsorbed particles and overall pesticide runoff risk

Insecticide Active Ingredient (common name)	Trade Name	Solution runoff Potential[1]	Adsorption Runoff Potential[2]	Overall Runoff Risk[3]
chlorpyrifos	Lorsban, Dursban	high	intermediate	very high
cypermethrin	Ammo, Mustang	low	high	high
cyfluthrin	Baythroid	low	intermediate	high
lambda-cyhalothrin	Warrior, Karate	low	intermediate	high
carbaryl	Sevin	intermediate	low	moderate
malathion	Malathion	intermediate	low	moderate
phosmet	Imidan	intermediate	low	moderate
carbofuran	Furadan	low	intermediate	moderate
dimethoate	Cygon	low	low	low

Notes:

[1] Likelihood that the active ingredient will transport from the area of treatment as dissolved chemical in runoff.

[2] Likelihood that the active ingredient will transport from the area of treatment as attachment to soil or sediment particles in runoff.

[3] Overall likelihood to cause negative impact on surface water quality as a product of the runoff potential and the aquatic toxicity of the pesticide.

Source: Pesticide Choice: Best Management Practice for Protecting Surface Water Quality in Agriculture, UCANR Publication 8161, http://anrcatalog.ucdavis.edu/pdf/8161.pdf

AVOIDING WATER QUALITY EXCEEDANCES

The risk of having pesticide residues in irrigation and storm water runoff depends on factors such as land slope, soil type, climate, irrigation management, and pesticide application practices. The properties of the pesticide and proximity to sensitive areas are also important factors. Determining the risk of your operation impacting water quality is not an easy matter. The factors interact with each other, some compounding each other and others mitigating each other. For example, a soil may be susceptible to pesticide sediment loss but once planted to alfalfa the erosion hazard would be minimized.

Assessing the Risk of Off-Site Movement

Obviously, each site has different characteristics which determine the risk of off-site movement. Those with greater risks are those with more land slope and poor infiltration, those close to sensitive areas and those with uncontrolled runoff from surface irrigation. Once an assessment of the risk is made and found to be significant, a review of management practices can be made and implemented to mitigate the risk.

PESTICIDE APPLICATION PRACTICES

The ways in which pesticides are stored and used affect pesticide fate and transport in the environment are listed below:

- Transportation, storage, disposal of containers and rinsate, and spill prevention are basic concerns in handling pesticides safely and keeping them on-site.
- Location of sensitive areas, like sinkholes, depressions, wells, surface water, public institutions and private buildings, relative to where pesticides are applied influence the chances of pesticides moving to undesired areas.
- Existence of buffer zones around such sites affects delivery of pesticides off-site.
- Selection of appropriate pesticides for the pest, crop, and site will reduce the likelihood of pesticide losses.
- Knowledge and practice of pesticide applicators and their adherence to product labels help reduce the chances of undesirable pesticide transport.
- Select chemicals on the basis of environmental impact in addition to efficacy and costs.
- Time application’s when the potential for storm runoff is low.
- Minimizing pesticide/herbicide use.
- Mix and load sprayers properly and away from drain ways.
- Calibrate your equipment properly.

IRRIGATION WATER MANAGEMENT PRACTICES

Most alfalfa field are surface irrigated, resulting in runoff each irrigation. The runoff can contain pesticides if they were applied prior to irrigation. Measurements have been made of runoff water containing chlorpyrifos in exceedance of the water quality standard for three irrigations (60 days after application). Under these cases runoff control or treatment is necessary to mitigate the risk of off-site movement.

Runoff Control. Minimizing or eliminating irrigation water runoff can significantly reduce water quality impacts. Irrigation runoff retained on a grower’s property is not subject to regulation under the Irrigated Lands Waiver program.

A number of irrigation water management (IWM) practices that minimize irrigation water runoff and collect any remaining runoff for reuse can be implemented as part of a grower’s irrigation practices. They include:

Applying the correct amount of water. Avoiding over-irrigation that can result in deep percolation (drainage) losses and in excessive tailwater runoff is sound irrigation water management. Determining the correct irrigation amount is often referred to as irrigation scheduling. An effective irrigation scheduling technique is to use crop evapotranspiration (ET) to determine the amount of water depleted from the soil profile since the last irrigation. California has an excellent ET system, the CIMIS (California Irrigation Management Information System) network, provided free by a California Department of Water Resources. This system provides

ET information on a daily basis for a large number of California locations. Simply log in to http://wwwcimis.water.ca.gov for this information.

Using historically averaged ET information can also be very beneficial (see Table 4). Table 4 provides estimates of alfalfa water use for various locations in California.

It is important to measure the amount of applied water to determine if the applied irrigation amount agrees with the required amount determined by the ET estimates. The best method of measuring applied water is to have a flow meter installed on the water source. If this is not possible, other methods of measuring the applied water are available. The web site, http://gwpa.uckac.edu/06.htm outlines various methods of measuring applied water and addresses how the measurements can be interpreted.

It is often difficult to apply only the desired amount of irrigation water with border flood systems often used to irrigate alfalfa. Frequently excess water must be applied to adequately irrigate the entire field. Some IWM techniques can be helpful though in the minimizing tailwater runoff and achieving improved irrigation efficiency.

- Shorter field lengths allow application of a lesser amount of water per irrigation as compared to longer fields. This lesser irrigation amount often more closely matches the desired irrigation amount determined from ET information.
- Closely manage the irrigation event so that the water is shut off in a timely manner. Often water can be turned off to a border check before it reaches the end of the field. Even after shutoff, the water flowing down the border check will continue to an advance across the field. If the shutoff is timed properly, the tail end of the field will adequately irrigated without generating excessive tailwater.

Using Tailwater Return Systems. Instead of discharging irrigation tailwater off the property, which is inefficient and makes the runoff subject to regulation under the Irrigated Lands Waiver program, tailwater can be collected and reused for irrigation during another irrigation set or for irrigation on another field. Tailwater return systems, which collect tailwater for reuse later, increase irrigation efficiency and allow a grower to minimize or eliminate water quality impacts from irrigation runoff.

The tailwater return system usually consists of a collection ditch that transports tailwater runoff to a storage pond. The tailwater pond stores runoff until it can be beneficially used for irrigation. The pond often has a permanently installed pump with a discharge pipeline that takes water to a point where it can be added to the irrigation supply. Portable, engine-driven pumps can also be used to remove water from the pond, pumping it to a location for reuse. More information on tailwater return systems, including information on cost and management, a free publication *Reducing Runoff from Irrigated Lands: Tailwater Return Systems* is available at http://anrcatalog.ucdavis.edu/InOrder/Shop/ItemDetails.asp?ItemNo=8225.

Table 4. Estimates of alfalfa crop water use (ET) for various locations in California. Alfalfa crop water use (inches per day during period)

Date	Shafter	Parlier	Davis	McArthur	Brawley
Jan 1-15	0.03	0.03	0.03	0.02	0.07
Jan 16-31	0.05	0.04	0.05	0.03	0.09
Feb 1-15	0.07	0.06	0.06	0.04	0.10
Feb 16-28	0.09	0.08	0.09	0.07	0.13
March 1-15	0.11	0.10	0.09	0.08	0.16
March 16-31	0.14	0.13	0.14	0.11	0.19
Apr 1-15	0.19	0.17	0.18	0.14	0.22
Apr 16-30	0.20	0.19	0.20	0.14	0.25
May 1-15	0.24	0.22	0.23	0.18	0.28
May 16-31	0.26	0.24	0.24	0.19	0.29
June 1-15	0.27	0.26	0.28	0.22	0.31
June 16-31	0.28	0.27	0.29	0.25	0.32
July 1-15	0.28	0.27	0.29	0.27	0.31
July 16-31	0.26	0.25	0.27	0.25	0.29
Aug 1-15	0.25	0.24	0.26	0.25	0.29
Aug 16-31	0.23	0.22	0.24	0.22	0.28
Sept 1-15	0.21	0.19	0.21	0.18	0.26
Sept 16-30	0.18	0.15	0.18	0.14	0.22
Oct 1-15	0.16	0.13	0.16	0.12	0.19
Oct 16-31	0.12	0.09	0.12	0.08	0.15
Nov 1-15	0.08	0.07	0.09	0.05	0.12
Nov 16-30	0.08	0.04	0.06	0.03	0.10
Dec 1-15	0.05	0.03	0.05	0.02	0.07
Dec 16-31	0.03	0.02	0.04	0.02	0.07

TREATMENT OF PESTICIDES IN RUNOFF WATERS

Treatment consists of removing or deactivating the pesticide before discharging the runoff from your property. The appropriate practice depends on the type and properties of the pesticide. Alfalfa growers do not usually have a sediment discharge issue as the runoff water exits the check. However, as the water increases in velocity in the tail ditch, sediment that has attached pyrethroids can be suspended and moved with the runoff water. As an example, sediment-carrying pyrethroids can be settled out in basins or in vegetated ditches before ultimate discharge (Figure 4). These practices have had mixed results in that the basin must be large enough to slow the water velocity enough for the finest of the particles to settle. Results of a 2 hr water detention was successful in reducing the total amount of particles, however the finest particles carrying the pyrethroids were not reduced resulting in runoff that caused a water toxicity exceedance. The results using vegetated ditches was more encouraging by removing 62-73% of the suspended solids and causing no exceedance (Hanson, Fulton and Cahn). The concern with this practice is the reduced velocity required. A ratio of 1:35 was necessary to reduce the runoff flow rate to 90 gallons per minute. Using a wider ditch with a flat bottom may provide a more practical solution.

Figure 4. Vegetated Ditch and Sediment Trap

Source: Hanson, Fulton and Cahn

Polyacrylamide, or PAM, is a large molecule applied to water which stabilizes the soil structure, increasing infiltration, and flocculating sediments. In a runoff ditch, it can be applied to remove the sediments brought into suspension by the runoff waters' increased velocity once in the ditch. Essentially, the PAM attracts the small soil particles to which the pyrethroids are attached, increasing in weight of particles and dropping out of the discharge water. The use of a short-term settling basin is also helpful.

Another management practice to reduce the risk of sediment-attached pesticides is to avoid spraying the tail ditch with the material.

A new management practice available is the use of a material to hydrolyze or deactivate the material. The material is Landguard OP-A, available from Orica Water Care Inc. It is an enzyme that rapidly breaks down specific organophosphate pesticides reducing their toxicity and half-life. Landguard OP-A is registered for sale and use in the U.S. in early 2006 as an industrial chemical. It does not require registration as a pesticide since it has no pesticidal qualities. It will be available through two major agricultural distributor/retailers in California in January 2008.

Use of the product requires mixing the packaged granular enzyme into a container with water. The solubilized material is dosed slowly into the tail ditch at a rate depending on the maximum rate of runoff expected. Figure 5 is a runoff hydrograph showing a typical tail ditch flow for a single alfalfa irrigation set. On-flow rate was 2000 gallons per minute into three 53-foot checks. Checks were 1630 feet in length. The maximum runoff flow was near 700 gallons per minute.

The Landguard solution must be applied for the entire irrigation runoff period. Figure 5 also shows a simple manual turn-on/off dosing unit.

Figure 5.Typical border check irrigation runoff hydrograph and simple dosing unit

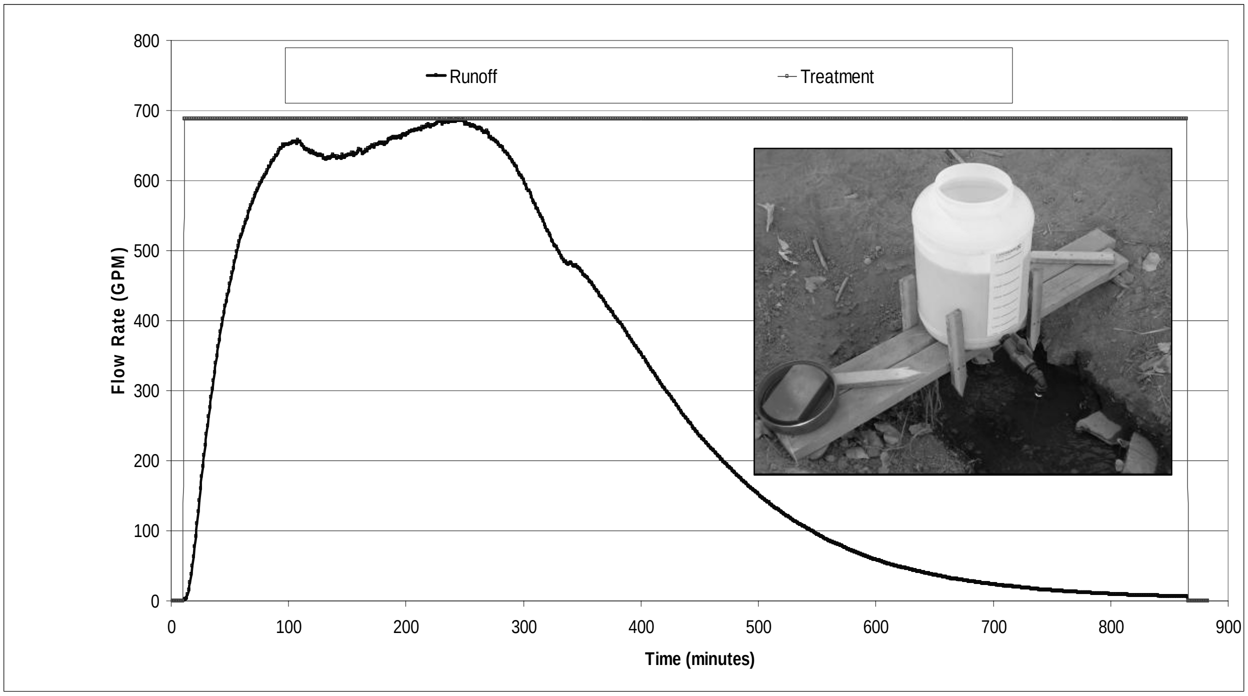
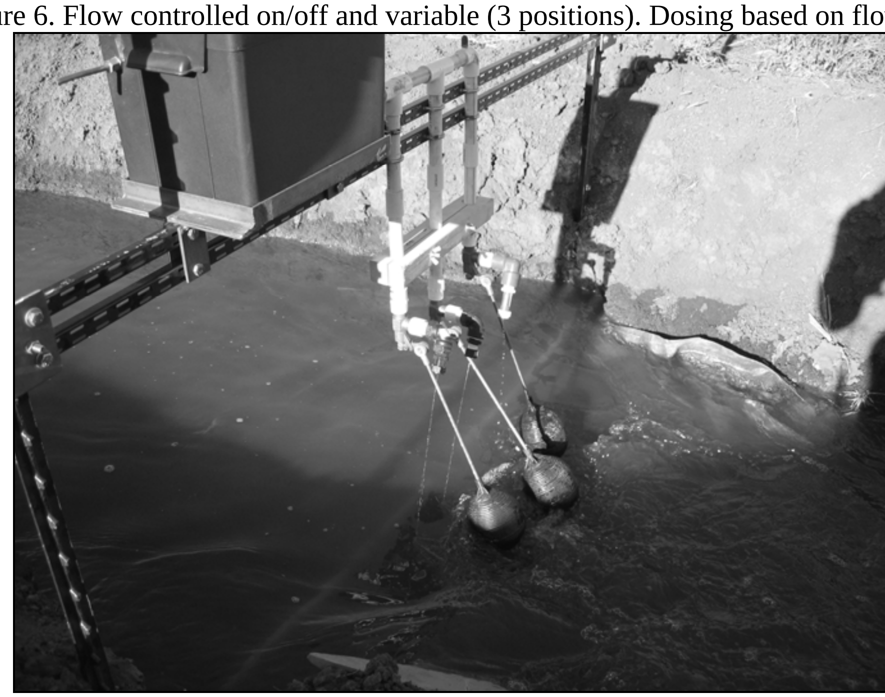


Figure 6. Flow controlled on/off and variable (3 positions). Dosing based on flow rate



Landguard OP-A when applied at the correct strength works rapidly to reduce the concentration of the OP pesticide. It will reduce the typical concentration of chlorpyrifos in alfalfa runoff by 99% within 15 minutes.

SUMMARY

Reducing pesticide residues in agricultural runoff has become a necessity to retain valuable chemical tools in alfalfa production. Some of the most frequently used chemicals are those which are most commonly found in the monitoring of watershed in California. In the past, growers were focused on following the label precautions, material efficacy, and cost. Today we must add the management practices to ensure pesticide residues do not enter surface and ground water sources. These practices must be effective in reducing water quality exceedances and be cost effective to implement. There is one thing about water quality monitoring to remember—there is a zero tolerance for exceedance and there is no grading on the curve. Therefore we must all take responsibility for our actions and employ practices to ensure exceedances do not occur.