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Chlorpyrifos Runoff from a Flood-Irrigated Alfalfa Field

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Introduction

Pesticide runoff from irrigated agricultural field has been identified as a major contributor to pesticide contamination in surface waters during irrigation season (Prichard, 2010). Understanding the mechanisms of this offsite movement is essential to finding solutions to the problem. Alfalfa was selected due to its common use of gravity irrigation and large acreage in California. Chlorpyrifos is a broad-spectrum organophosphorus insecticide commonly used to control soil and foliage pests in many crops including alfalfa, tree crops, wine grapes and vegetable crops. In alfalfa cultivation, chlorpyrifos is often used during spring and summer to control alfalfa weevils, army worms and other insects. It has been frequently detected in the surface waters of agricultural areas in California (Zhang, 2012). This study aims at quantifying the fate and transport mechanisms of chlorpyrifos from flood irrigated alfalfa. The objectives of this study are two fold: (1) quantify irrigation runoff from flood irrigation; (2) study fate and transport of chlorpyrifos in field conditions.

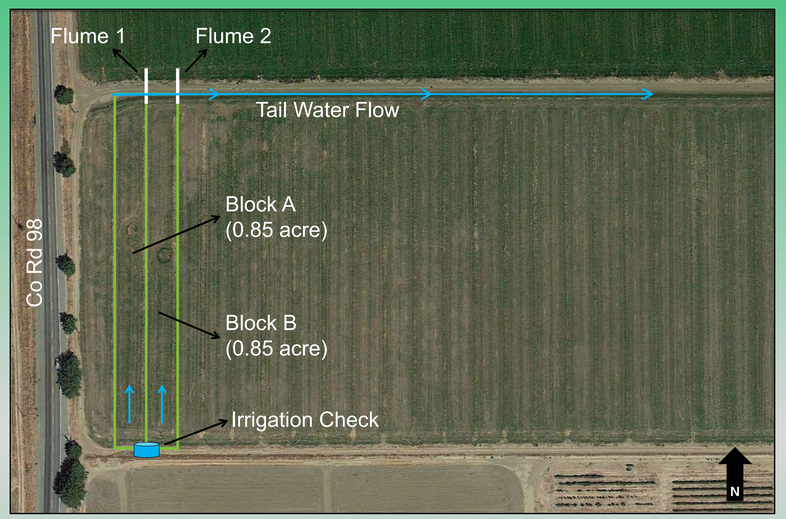

Figure 1. Study site

Materials & Methods

Study Site and Pesticide Treatment

•Site is located in a 32 acre field of well-established alfalfa stands at UC Davis with soils of Brentwood silty-clay loam with high silt (47.8%) and clay (33.5%) content.

•Study area consists of two blocks watered by check flood irrigation

•Lorsban Advanced was applied with an application rate of 1 pint/acre (0.5 kg/ha of active ingredient) with a ground sprayer (Figure 2); tank mixture sample were collected before application.

Sample Collection

•Adsorbing Kimbie® sheets were placed on plant canopy prior to spray to quantify mass deposition and were collected 6 hours after spray.

•Plant and soil samples were collected prior to and following pesticide application at 6 hours, 1, 7, 21, and 30 days post application.

•Composite soil samples were collected from 4 random locations with a soil auger at two depths (0-15 and 15-30 cm); 4 composite plant samples were collected using the ring-toss method.

•Water samples for 3 irrigation events were collected in 1 L amber bottles every 10-30 min from the tail water with at least 8 samples per event.

Chemical Analysis

•Soil, plant, and deposition samples were analyzed for pesticide concentrations by the California Department of Food and Agriculture Laboratory using ES LC/MS/MS.

•Water samples were analyzed at the UC Davis Aquatic Toxicology lab using commercial ELISA kits manufactured by Modern Water, Inc.

Flow Measurements

•Water inflow was measured with a propeller flow meter attached to the inflow pipe and the runoff flow was measured with the installed flumes within the ditch and a Doppler flow meter.

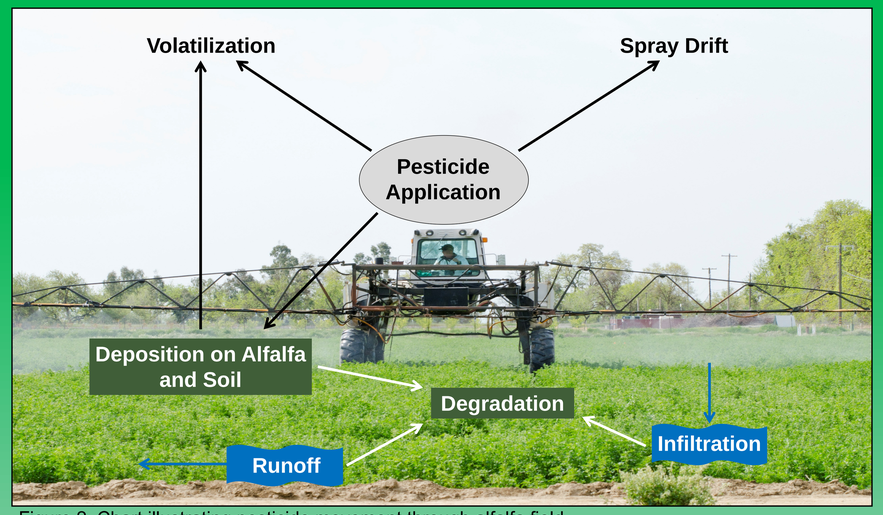

Figure 2. Chart illustrating pesticide movement through alfalfa field

Results and Discussion

- Mass deposition sheet samples received an average of 12.8 mg chlorpyrifos per square meter of surface area, with a standard deviation of 1.5 mg/m^2. The small differences among samples suggested a uniform distribution of chlorpyrifos across the study site.
- Deposited chlorpyrifos measured by the mass deposition sheets only accounted for 36% of chlorpyrifos applied to the field; the loss could be due to inaccurate application, volatilization (Henry's Constant=0.478 Pa m^3 mol^{-1}), drift, or degradation.

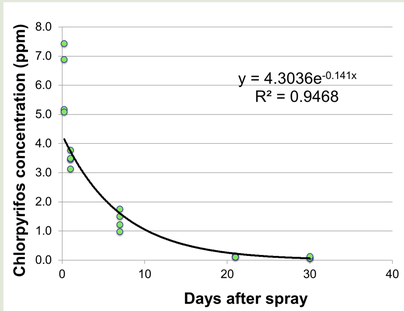

Figure 3. Chlorpyrifos degradation on alfalfa

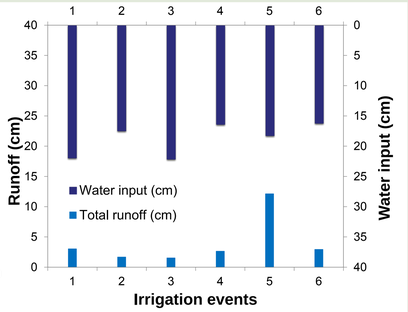

Figure 4. Irrigation water input and runoff

- More than 90% of chlorpyrifos was found on alfalfa with initial concentrations ranged from 5.1 to 7.4 ppm. This is because the pesticide was applied when the plant canopy was fully developed and the pesticide was intercepted by alfalfa before landing to the soil surface.
- No detections were found in the soil columns, suggesting that leaching to ground water is unlikely to happen at this study site for chlorpyrifos.

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Table 1. Percent mass loss of chlorpyrifos during irrigation events

Event date	Block	Inflow (gal/min)	Water input (cm)	Runoff (cm)	% Water Runoff	% Mass Loss in Runoff
5/21/2012	B	500	21.9	3	13.8	0.1279
5/22/2012	A	483.3	17.4	1.7	9.6	0.1492
6/15/2012	B	473.3	22.1	1.5	7	0.0460
6/16/2012	A	449	16.4	2.6	16.1	0.0556
8/28/2012	B	527.1	18.2	12.1	66.6	0.0013
8/29/2012	A	523.3	16.2	2.9	18.2	0.0005

Table 2. Soil properties from field site

Soil Properties Tested	Top Layer		Bottom Layer	
	Mean	Stdv	Mean	Stdv
Depth (cm)	0-15		15-30	
%sand	42.85	2.13	43.94	2.9
%silt	36.49	4.16	33.78	4.64
%clay	20.66	2.52	22.28	2.02
Bulk density	1.42	0.06	1.46	0.09
Field capacity (1/3 bar) (m3/m3)	0.317	0.046	0.309	0.015
Saturation moisture content (m3/m3)	0.496	0.040	0.476	0.025
Wilting point (15 bar) (m3/m3)	0.191	0.008	0.191	0.020
Saturate hydraulic conductivity (cm/hr)	1.52	1.313	1.26	1.921
Soil pH	7.22	0.068	7.18	0.078

Results and Discussion Continued

- Even with a K_{oc} of 8151, the majority of chlorpyrifos in tail water is in dissolved form due to low sediment concentration in runoff.
- Plant samples showed a significant trend in degradation with P value <0.001. The first order degradation model was fitted as $y = 4.3036e^{-0.141x}$ with significant coefficients and a R^2 value of 0.95. Using the coefficients, the plant half-life was calculated as 5 days. (Figure 3)
- Runoff percentage of irrigated water was lower than 20% in all irrigation events excluding the 8/28/2012 irrigation event. (Table 1)
- Chlorpyrifos concentrations in runoff water ranged from 0.33 to 0.63 µg/L for the first two irrigation (42 and 67 days after application), which exceeded the U.S. EPA lowest acute aquatic life benchmark for fresh water organisms (0.04 µg/L) (U.S. EPA, 2013); concentrations dropped to below the detection limit of 0.05 µg/L in the last irrigation events which is 143&144 days after spray.
- The highest percent loss of chlorpyrifos through field runoff occurred during the first irrigation after spray with 0.128% and 0.149% for block B and block A, respectively; amounts of chlorpyrifos decreased through the next two irrigation events with the lowest percent loss at 0.0005% on August 29, 2012. (Table 2)

Conclusion

- Majority of chlorpyrifos applied was captured by alfalfa canopy
- Chlorpyrifos degradation in alfalfa follows the first-order degradation model with a half-life of 5 days.
- Runoff water from alfalfa field contains low concentrations of sediment and most of the chlorpyrifos moved offsite as dissolved in water.
- 67 days after application, chlorpyrifos was detected in runoff water with low concentrations, but still higher than the U.S. EPA lowest acute aquatic life benchmark for fresh water organisms.
- Surface runoff is a less significant pathway of loss for chlorpyrifos compared to the initial loss of the chemical when it was applied or through degradation on the alfalfa plant. Leaching to groundwater is unlikely at this study site.

References

Prichard, T. 2010. Preventing off-site movement of pesticides in alfalfa and corn. IN Proceedings, 2010 California Alfalfa and Forage Symposium and Corn/Cereal Silage Mini-Symposium, Visalia, CA, 1-2 December, 2010

Zhang, X., K. Starner, and F. Spurlock. 2012. Analysis of Chlorpyrifos Agricultural Use in Regions of Frequent Surface Water Detections in California, USA. Bulletin of Environmental Contamination and Toxicology. 89:978-984

U.S. EPA, 2013. U.S. EPA Office of Pesticide Programs' Aquatic Life Benchmarks data available at http://www.epa.gov/oppefed1/ecorisk_ders/aquatic_life_benchmark.htm (accessed on April 22, 2013).

Acknowledgements

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