Environmental Pollution 157 (2009) 287–294

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Residential runoff as a source of pyrethroid pesticides to urban creeks

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Pyrethroid insecticides regularly detected in residential runoff at toxicologically significant concentrations.

ARTICLE INFO

Article history:
Received 6 March 2008
Received in revised form 17 June 2008
Accepted 22 June 2008

Keywords:
Pyrethroid
Bifenthrin
Urban runoff
Stormwater

ABSTRACT

Pyrethroid pesticides occur in urban creek sediments at concentrations acutely toxic to sensitive aquatic life. To better understand the source of these residues, runoff from residential neighborhoods around Sacramento, California was monitored over the course of a year. Pyrethroids were present in every sample. Bifenthrin, found at up to 73 ng/L in the water and 1211 ng/g on suspended sediment, was the pyrethroid of greatest toxicological concern, with cypermethrin and cyfluthrin of secondary concern. The bifenthrin could have originated either from use by consumers or professional pest controllers, though the seasonal pattern of discharge from the drain was more consistent with professional use as the dominant source. Stormwater runoff was more important than dry season irrigation runoff in transporting pyrethroids to urban creeks. A single intense storm was capable of discharging as much bifenthrin to an urban creek in 3 h as that discharged over 6 months of irrigation runoff.

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1. Introduction

Pyrethroid insecticides have replaced organophosphates like diazinon and chlorpyrifos for pest control in urban environments. Pyrethroids are widely used by professional pest controllers for termiticides, landscape application, or as perimeter treatments to keep pests out of structures. In addition, they are the dominant insecticides among retail sales to consumers. Due to these uses, they have been reported in nearly all sediment samples tested from approximately 20 urban creeks in California (Weston et al., 2005, 2006; Amweg et al., 2006; Ng et al., in press; Budd et al., 2007). In the majority of instances, they have been present at concentrations exceeding toxicity thresholds for sensitive invertebrates, and testing with the amphipod *Hyalella azteca* has commonly shown acute toxicity. Though the presence of other toxicants cannot be ruled out, the pyrethroids alone have been in sufficient concentrations to explain this toxicity. There is also evidence from toxicity identification evaluation procedures that suggests a dominant role of pyrethroids in this toxicity (Weston et al., 2006; Amweg and Weston, 2007; Weston and Amweg, 2007). There is no reason to believe these findings are unique to California, though there has been very little monitoring for these compounds elsewhere.

It has been assumed that storm drain outfalls were the primary source of pyrethroids to creeks because the systems studied lacked any other potential sources and because the highest concentrations were often found in sediments in front of drain outfalls (Weston et al., 2005; Amweg et al., 2006). However, there are no published data on direct quantification of pyrethroids in urban runoff. This study of storm drains serving residential areas of northern California was designed to determine the frequency of detection and concentrations of pyrethroids in urban runoff. We also examined seasonal patterns in the relative abundance and concentrations of pyrethroids in runoff to identify potential sources.

2. Materials and methods

2.1. Study design

Two storm drain outfalls were monitored from July 2006 to April 2007. The first drain, located in Roseville, CA, north of Sacramento, consisted of three adjacent concrete pipes, 0.9–1.2 m in diameter, discharging at the head of a small ravine (38.80263, −121.33885). The three drains combined serve 400 single-family homes, mostly 1–6 years old. Lot sizes are approximately 0.09 ha. Runoff from the three drains merges into a single stream and enters Pleasant Grove Creek. The sediment in this location is known to contain bifenthrin, cyfluthrin and cypermethrin at concentrations acutely toxic to *H. azteca*, as well as lower concentrations of permethrin, deltamethrin, and lambda-cyhalothrin (Weston et al., 2005). We will refer to the three adjacent drains as a single drain, since flow was measured after their confluence and chemistry samples were a composite of the three discharges.

The second drain was located in Elk Grove, CA, south of Sacramento (38.40792, −121.35069) and served 100 single-family residences. Runoff emerged from a single 0.8 m pipe and flowed to a stormwater detention basin.

The area's climate is characterized by a dry season, from May through October, with flow from drains largely limited to landscape irrigation runoff. Drain discharges were sampled 4 times during the 2006 dry season (July 17, July 30, August 20,

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doi:10.1016/j.envpol.2008.06.037

September 9: all between 5:00 and 10:00 AM). The wet season extends from November to April. Flow from the drains is heavy during rain events but minimal otherwise. Drains were sampled during five rain events in late 2006 and early 2007 (Fig. 1). One to three samples were collected in any given rain event, depending on rain intensity and duration. The five rain events yielded eight samples at each site. Elk Grove sampling captured the first significant rain event of the season (mid-November). An isolated storm over Roseville produced substantial rain in early November, prior to initiation of the Roseville wet season sampling.

A significant constraint in the drain sampling was the unusually low rainfall during the 2006/2007 wet season. Rainfall accumulation was only half the amount typical of most years. There were only two occasions in Roseville where 24 h precipitation exceeded 2.5 cm, compared to, for example, seven such occasions in the previous year.

2.2. Field sampling procedures

Water samples for pesticide analysis were taken by immersing a 2-L solvent-cleaned glass bottle below the water surface, or when depths were too shallow, by repeatedly dipping a stainless steel container and transferring its contents to the bottle. Samples were taken at the mouths of the drains. At the three adjacent Roseville drains, we took a composite sample of those drains flowing at the time of sampling. Samples were held on ice until return to the laboratory where they were refrigerated at 4 °C.

Pyrethroids are strongly hydrophobic, with log K_{oc} values typically about 5.5 (Laskowski, 2002). Therefore, much of the pyrethroid in runoff samples may be associated with suspended particulates. Large volume samples were occasionally collected to quantify suspended sediment-associated pyrethroids (July 30 and August 20, 2006; February 9 and 26, 2007). Twenty-liter stainless steel kegs were filled by pumping water through stainless steel tubes using a diaphragm pump. A sample consisted of 8–12 kegs (160–240 L).

Flow from drains was usually measured using a Swoffer 2100-C140 current meter (Swoffer Instruments, Seattle, WA, USA). The cross-sectional area of flow was divided into adjacent rectangles 10 cm in width, and a velocity measurement was taken within each rectangle at a depth 60% of the distance from the water surface to the bottom (Rantz, 1982). At Elk Grove, when flow was low (<6 L/s), it was possible to measure flow by time required to fill a container of known volume.

Sediment samples for pesticide analysis were obtained from the bottom of the discharge pipes at the mouth of each drain once during the dry season (August 20, 2006). Bed sediment was collected 3 times (September 9, 2006; January 3 and April 21, 2007) from Pleasant Grove Creek 30 m downstream from where flow from the Roseville drain entered. The wet season bed samples were collected several weeks after significant rainfall. The upper 1 cm of the sediment was sampled with a stainless steel scoop.

2.3. Sample analyses

Water samples were liquid:liquid extracted following EPA Method 3510C. Surrogate standards (4,4′-dibromooctafluorobiphenyl and decachlorobiphenyl; Supelco, Bellefonte, PA, USA) were added, and then 1 L of the sample was poured into a 2-L separatory funnel, and extracted with three consecutive additions of 60 ml dichloromethane. The process was repeated with the second liter of sample, and the sample bottle rinsed with an additional 60 ml. All dichloromethane extracts were combined and reduced to a volume of 10 ml under a stream of nitrogen for shipment to the analytical laboratory.

After arrival at the analytical laboratory, extracts were solvent exchanged to hexane, concentrated to 1 ml, and eluted through a dual layer solid phase extraction cartridge containing primary/secondary amine and graphitized black carbon. Each cartridge was conditioned with 3 ml hexane. The sample tube was washed with three rinses of 0.5 ml hexane added to the cartridge. The sample was eluted with 7 ml of 30% dichloromethane in hexane. Samples were then concentrated, transferred to gas chromatography vials, reduced in volume to near dryness, and reconstituted to 1 ml in 0.1% acetic acid in hexane for analyses.

Sediment samples were extracted using a matrix-dispersive accelerated solvent extraction method (You et al., in press) using a Dionex 200 with 33 ml stainless steel cells and 60 ml glass collection vials (Dionex, Sunnyvale, CA, USA). Before extraction, sediment was centrifuged to remove excess water and homogenized. Ten grams of wet sediment were mixed with diatomaceous earth, normal phase dispersion absorbent, 2 g of copper powder, and 1–3 g of silica, and transferred into the cells. The

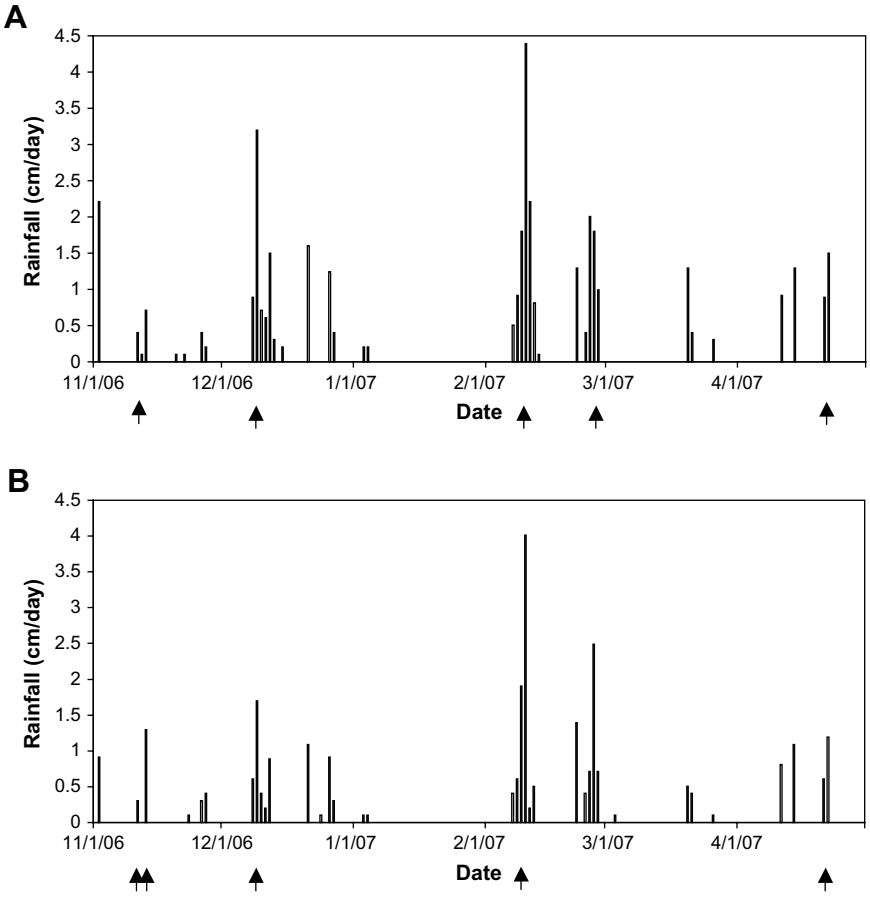

Fig. 1. Daily rainfall accumulation during the study period at: (A) the Chicago weather station, 11 km south of the Roseville drain, and (B) the Elk Grove Fish Hatchery weather station, 3 km northeast of the Elk Grove drain. The arrows along the *x*-axes indicate the storm events that were sampled. Two to three samples approximately 12 h apart were taken and analyzed independently from the early December and early February storms at both sites, and two samples were collected during the first November rain event at Elk Grove. One sample was taken during the other rain events.

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