Mitigation of pesticide runoff using a bioreactor in Santa Maria Valley

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INTRODUCTION

Irrigation water runoff and water release from treated agricultural fields have the potential to contaminate local surface waters and consequently lead to toxicity in sensitive aquatic organisms (Ensminger et al., 2011). In an effort to mitigate contaminated runoff, we are currently evaluating bioreactors as a method to improve runoff water quality.

Denitrifying bioreactors are a technology currently undergoing research and development to reduce nitrate and pesticide concentrations in runoff water (Schipper et al., 2010; Zheng and Dunets). Nitrate is removed from the water and converted to nitrogen gas by denitrifying bacteria living in the anoxic wood chip bioreactor that use the wood as a carbon source (Leverenz et al., 2010). Bioreactors have been studied for their ability to reduce phosphorous and herbicide loads as well, but with a limited crop rotation and pesticide detection list (Ranaivoson et al., 2012; Pinilla et al., 2007). One study that monitored for phosphorous and herbicide (atrazine and acetochlor) removal found that both are removed from water by the bioreactor but likely through adsorption to woodchips (Ranaivoson et al., 2012). More specifically, 70% of acetochlor load was reduced while 53% of atrazine was removed. Moreover, phosphorous load was reduced by an average of 79% (Ranaivoson et al., 2012). These limited studies reveal the need for further field-scale research into bioreactor pesticide removal. For example, not all pesticides passing through the bioreactor are likely to be removed at equal rates or experience similar degradation mechanisms. Those with a high K_{ow} like pyrethroids might adsorb to the woodchips while those with a low K_{ow} might be degraded by microbes. The unique physical-chemical properties of each pesticide could determine how well each is removed in the bioreactor; the objective of this project was to identify which pesticides are best removed by the bioreactor.

The Coastal San Luis Resource Conservation District (CSLRCD) has constructed a woodchip bioreactor lined with a 40-mm heavy duty agricultural liner and fed by water from Little Oso Flaco Lake in San Luis Obispo County, California. Source water is pumped several hundred yards to the bioreactor through a PVC pipe and distributed over about half the length of the bioreactor through a gated irrigation pipe (Figures 1–2). After filling, the bioreactor gravity drains over a period of several days back into Little Oso Flaco Lake then refills again. The State Water Resources Control Board (SWRCB) funded the project through the Central Coast Regional Water Quality Control Board (CCRWQCB). The California Department of Parks and Recreation (State Parks) is the landowner of the project site (CSLRCD, 2014). Bioreactor construction was completed by October 30, 2014, and was monitored for water volume treated, nitrate concentration reduction, and nitrate load reduction. A total of 360,000 gallons were treated, average concentration was reduced by 12 parts per million or ppm (average inflow of 20 ppm and average outflow of 8 ppm) and 36 pounds of nitrate as nitrogen was removed (CSLRCD, 2014). In this study, the California Department of Pesticide Regulation (CDPR) monitored for pesticide concentrations to determine the potential of a constructed woodchip bioreactor to remove pesticides from surface water.

MATERIALS AND METHODS

Two water sampling events were conducted in 2015 and 2016 at the Oso Flaco bioreactor. Water samples for pesticide analysis were collected in December 2015 and May 2016. In December 2015, samples were collected at an upstream site to determine pesticide load into Little Oso Flaco Lake and at the bioreactor inlet (Figure 3). Water from the outlet was not sampled during this event because the intent was to understand pesticide loading into the bioreactor. Samples from December were analyzed for pyrethroids, organophosphates, and imidacloprid. All samples were collected in 1-liter amber bottles then submitted for chemical analysis to the Center for Analytical Chemistry, California Department of Food and Agriculture (CDFA). In May 2016, samples were collected at the bioreactor inlet and outlet while a separate study collected samples at the same upstream site. The organophosphorus screen included the pesticides dimethoate, methidathion, malathion, and chlorpyrifos. Bifenthrin, lambda-cyhalothrin, permethrin (cis and trans), cyfluthrin, fenvalerate/esfenvalerate, and fenpropathrin were in the pyrethroid analytical chemistry screen.

RESULTS

Water samples collected at the upstream site in December contained a mixture of pesticides whereas samples from the bioreactor inlet only contained a low concentration of imidacloprid and a trace amount of malathion. A similar mixture of pesticides was detected at the upstream site in May 2016 and the same two pesticides were identified in the bioreactor inlet water (Table 1). Imidacloprid was the one pesticide detected at the outlet, with a concentration of 0.227 ppb, which was higher than the concentration detected at the inlet.

DISCUSSION

The intent of initial sampling was to determine the pesticide load from Oso Flaco Creek (upstream) into Little Oso Flaco Lake and subsequently into the bioreactor. In order to justify long-term sampling at the site and adequately address the study goals of quantifying bioreactor pesticide removal efficiency, it is imperative to have measurable concentrations of multiple pesticides flowing into the bioreactor. After two sampling events, this condition was not satisfied. While several pyrethroid insecticides were detected upstream in Oso Flaco Creek, they were not detectable in bioreactor inlet water. Since two insecticides were detected at low concentrations at the inlet, it is difficult to determine the overall effectiveness of the bioreactor for pesticide removal. As such, the goals of the study could not have been adequately achieved should sampling continue according to the methods outlined in the study protocol. Thus, we terminated the study after two sampling events.

In May, the concentration of imidacloprid was higher at the outlet than the inlet. These samples were collected at the same time at the inlet and outlet; the hydraulic retention time of the bioreactor was not determined. It is possible that the pulse of water that had been pumped into the bioreactor before our sampling (represented by the water that was collected as outlet water) simply had a higher concentration of imidacloprid than the pulse of water collected as the inlet water. Since samples were collected once from the bioreactor outlet, we do not have enough data to make conclusions about the ability of woodchip bioreactors to remove pesticides from water. Other woodchip bioreactors are currently in the early stages of operation, being constructed, or planned throughout California. DPR has started a project at one of these sites in Castroville on Sea Mist Farms in order to achieve goals similar to those for this study (Wagner, 2016).

Table 1. Pesticide concentrations in surface water from Oso Flaco Creek and the bioreactor inlet and outlet

	Site			Reporting Limit (ppb*)	USEPA Chronic Invertebrate Aquatic Life Benchmark (ppb)
Analyte	**Oso Flaco Creek**	**Bioreactor inlet (ppb)**	**Bioreactor outlet (ppb)**		
Dec-15					
Pyrethroids					
bifenthrin	0.00973	ND		0.001	0.0013
fenpropathrin	ND	ND		0.005	0.064
lambda cyhalothrin	0.0747	ND		0.002	0.002
permethrin cis	ND	ND		0.002	0.0014 (combined)
permethrin trans	ND	ND		0.005	
cyfluthrin	ND	ND		0.002	0.0074
cypermethrin	ND	ND		0.005	0.069
esfenvalerate/fenvalerate	0.0429	ND		0.005	0.017
Organophosphates					
chlorpyrifos	ND	ND		0.01	0.04
malathion	0.041	Trace		0.02	0.035
methidathion	ND	ND		0.05	0.66
dimethoate	ND	ND		0.04	0.5
imidacloprid	1.1	0.34		0.05	1.05
May-16					
Pyrethroids					
bifenthrin	0.00386	ND	ND	0.001	0.0013
fenpropathrin	ND	ND	ND	0.005	0.064
lambda cyhalothrin	0.00295	ND	ND	0.002	0.002
permethrin cis	ND	ND	ND	0.002	0.0014 (combined)
permethrin trans	ND	ND	ND	0.005	
cyfluthrin	ND	ND	ND	0.002	0.0074
cypermethrin	ND	ND	ND	0.005	0.069
esfenvalerate/fenvalerate	ND	ND	ND	0.005	0.017
Organophosphates					
chlorpyrifos	ND	ND	ND	0.01	0.04
malathion	ND	0.050	ND	0.02	0.035
methidathion	ND	ND	ND	0.05	0.66
dimethoate	0.08	ND	ND	0.04	0.5
imidacloprid	0.371	0.122	0.227	0.05	1.05

* Parts per billion

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APPENDIX

Figure 1. Bioreactor adjacent to Little Oso Flaco Lake with pump on and water flowing into bioreactor

Figure 2. Bioreactor adjacent to Little Oso Flaco Lake.

Figure 3. Sampling sites from December 2015 and May 2016 sampling events