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# Use of toxicity identification evaluations to determine the pesticide mitigation effectiveness of on-farm vegetated treatment systems

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*Toxicity identification evaluations identified key pesticides in agricultural runoff, and their concentrations were reduced by farmer-installed vegetated treatment systems.*

**Abstract**

Evidence of ecological impacts from pesticide runoff has prompted installation of vegetated treatment systems (VTS) along the central coast of California, USA. During five surveys of two on-farm VTS ponds, 88% of inlet and outlet water samples were toxic to *Ceriodaphnia dubia*. Toxicity identification evaluations (TIEs) indicated water toxicity was caused by diazinon at VTS-1, and chlorpyrifos at VTS-2. Diazinon levels in VTS-1 were variable, but high pulse inflow concentrations were reduced through dilution. At VTS-2, chlorpyrifos concentrations averaged 52% lower at the VTS outlet than at the inlet. Water concentrations of most other pesticides averaged 20–90% lower at VTS outlets. All VTS sediment samples were toxic to amphipods (*Hyalella azteca*). Sediment TIEs indicated toxicity was caused by cypermethrin and lambda-cyhalothrin at VTS-1, and chlorpyrifos and permethrin at VTS-2. As with water, sediment concentrations were lower at VTS outlets, indicating substantial reductions in farm runoff pesticide concentrations.


*Keywords:* Agricultural management practice; Pyrethroid pesticide; Organophosphate pesticide; Sediment TIE; Agricultural runoff

## 1. Introduction

Agricultural production currently utilizes over 12 million km$^2$ of the Earth's surface, and requires extensive commitments of labor and materials (FAO, 2007). Many costs of agriculture are external to farm operations, and accrue as losses in ecosystem services, including the beneficial uses of uncontaminated water. A variety of techniques are being evaluated worldwide to limit degradation of waterways from runoff of agricultural chemicals into aquatic habitats (Popov et al., 2006; Vu et al., 2006; Wang et al., 2005; Yates et al., 2007). In the USA, a number of studies have evaluated vegetated treatment systems (VTS), such as buffers, filter strips, ditches, ponds, and wetlands, to improve water quality (Dabney et al., 2006; Moore et al., 2006). Along the central coast of California, VTS are being installed by some of the 2500 operators who farm over 250 000 hectares year-round,

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producing nearly 200 different crops worth over $5 billion (CCRWQCB, 2004), while applying 7500 MT of pesticides annually (active ingredient; PAN, 2007).

Numerous studies have documented pesticide toxicity and ecological impacts in central coast streams (e.g., Anderson et al., 2003; CCAMP, 2007; Hunt et al., 1999; Phillips et al., 2006). An innovative regional program has been established to regulate non-point source pollution through adoption of conditional agricultural discharge permit waivers. Waiver conditions require farm water quality management plans, which often include installation of VTS to mitigate runoff of nutrients and pesticides (CCRWQCB, 2007). Many local farmers have installed VTS with assistance from the county Resource Conservation Districts and the National Resource Conservation Service. In this study, VTS built by growers were evaluated to provide feedback for system design and information for other growers considering VTS projects. Because this study evaluated VTS on working farms that receive intermittent runoff containing mixtures of unknown chemicals, it is distinct from previous studies that administered specific pesticides under controlled conditions into experimentally constructed VTS prototypes (e.g., Moore et al., 2001, 2006; Sherrard, 2004). For this reason, toxicity identification evaluations (TIEs) were employed here to identify chemicals most likely to cause biological impacts, so that VTS improvements could emphasize mitigation of these constituents. A number of advanced water and sediment TIE procedures were employed (e.g., Anderson et al., 2007; Wheelock et al., 2004).

We investigated two vegetated pond systems to evaluate their effectiveness in reducing concentrations of pesticides and nutrients. Both systems were originally constructed by the farm operators to retain sediment. Vegetation, primarily floating pennywort (*Hydrocotyle ranunculoides*), was established to provide shade and a carbon source for denitrification, as well as plant and microbial substrate for pesticide retention and breakdown. The fields draining to these VTS ponds have been treated with numerous pesticides, each potentially best mitigated by different VTS components that promote photolysis, hydrolysis, volatilization, sorption to plant surfaces, microbial metabolism, or deposition in sediments (Hapeman et al., 2003). To evaluate mitigation of these mixtures, this study employed a phased approach that began with toxicity testing of VTS inlets and outlets, followed by TIEs of water and sediment to identify chemicals of concern, and then chemical analysis to measure the differences in contaminant concentrations at the VTS inlets and outlets.

## 2. Methods

### 2.1. Vegetated treatment systems (VTS)

VTS-1 is a two-pond system vegetated with floating pennywort (*Hydrocotyle ranunculoides*), which formed a floating mat of roots and stems 0.5 to 1.0 m thick, with a typical biomass of 800 g/m$^2$. The primary inlet drained 50 hectares, and the secondary inlet drained 3.5 hectares of irrigated row crop vegetables. Water samples were collected just above the inlet (Fig. 1, A) and near the pond outlets (Fig. 1, B and C). Sediment samples were collected just above the inlet at A, and in the pond at C. VTS-2 is a single pond system vegetated with three aquatic plants: duckweed (*Lemna* sp.), watercress (*Nasturtium* sp.), and pennywort (*Hydrocotyle ranunculoides*), which formed a floating mat of roots and stems 0.01 to 1.0 m thick. The main inlet drained 35 hectares of greenhouse flower growing operations, and the secondary inputs drain three 1-hectare outdoor flower nursery areas. Water samples were collected just above the inlet (Fig. 2, A), and just below the outlet (Fig. 2, B). Sediment samples were collected in the input ditch at A, and in the pond immediately in front of the outlet culvert at B.

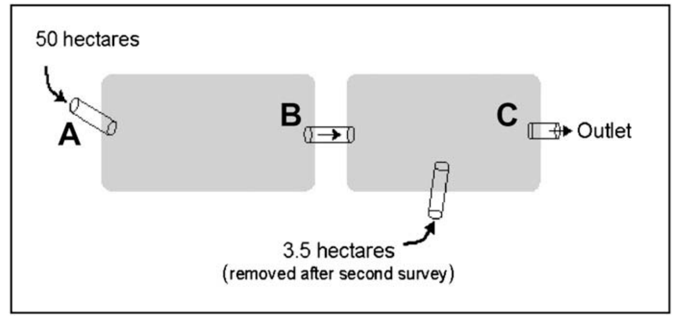


Fig. 1. Schematic diagram of ponds at VTS-1, with sampling stations A, B, and C. Upper pond is 27 m × 12 m × 1 m deep, and lower pond is 24 m × 12 m × 2 m deep.

To evaluate VTS effectiveness in reducing pesticide concentrations, water samples were collected at VTS inlets and outlets during five surveys, and sediment was collected once. Water samples at VTS inlets were collected as composites of three daily grab samples, while outflows were characterized by a single grab sample taken on the third day. This was done because parcels of water were presumed to channel through the ponds at rates faster than nominal residence times (Table 1). Compositing was selected as a means of obtaining an inlet sample that might be adequately compared to a day 3 outlet sample, in which constituent concentrations were "smeared" by mixing as the parcels passed through the ponds. Continuous sampling devices were not used because of the inconsistent pulsed nature of the runoff inflows. All sampling and analysis followed protocols and met objectives described by Puckett (2002). Details for all methods are given by Hunt et al. (2007).

Flow at the VTS-1 inlet was measured in an HS flume (Brakensiek et al., 1979), with an estimated error of less than 10%. Outflow at VTS-1 and inflow at VTS-2 were calculated from depth measured near the pipe inlets and rating curves developed using the broad crested weir equation and HEC-RAS 3.1.3 software (Brunner, 2002), with an estimated error of <25%.

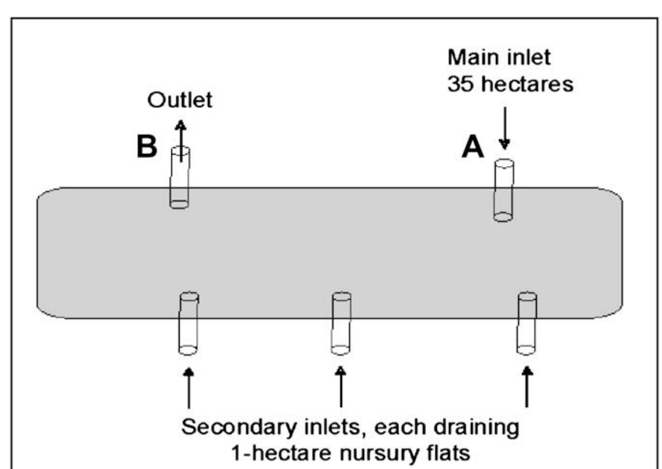


Fig. 2. Schematic diagram of pond at VTS-2, with sampling stations A and B. The pond is 70 m by 12 m × 1 to 2.5 m deep.