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Mitigation of atrazine, S-metolachlor, and diazinon using common emergent aquatic vegetation

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By the year 2050, the population of the United States is expected to reach over 418 million, while the global population will reach 9.6 billion. To provide safe food and fiber, agriculture must balance pesticide usage against impacts on natural resources. Challenges arise when storms cause runoff to be transported to aquatic receiving systems. Vegetated systems such as drainage ditches and constructed wetlands have been proposed as management practices to alleviate pesticide runoff. Twelve experimental mesocosms (1.3 × 0.71 × 0.61 m) were filled with sediment and planted with a monoculture of one of three wetland plant species (*Typha latifolia*, *Leersia oryzoides*, and *Sparganium americanum*). Three mesocosms remained unvegetated to serve as controls. All mesocosms were amended with 9.2 ± 0.8 μg/L, 12 ± 0.4 μg/L, and 3.1 ± 0.2 μg/L of atrazine, metolachlor, and diazinon, respectively, over a 4 hr hydraulic retention time to simulate storm runoff. Following the 4 hr amendment, non-amended water was flushed through mesocosms for an additional 4 hr. Outflow water samples were taken hourly from pre-amendment through 8 hr, and again at 12, 24, 48, 72, and 168 hr post-amendment. *L. oryzoides* and *T. latifolia* had mean atrazine, metolachlor, and diazinon retentions from 51%–55% for the first 4 hr of the experiment. Aside from *S. americanum* and atrazine (25% retention), unvegetated controls had the lowest pesticide retention (17%–28%) of all compared mesocosms. While native aquatic vegetation shows promise for mitigation of pesticide runoff, further studies increasing the hydraulic retention time for improved efficiency should be examined.

Introduction

Approximately 45% of the United States is agricultural land, with over 127 million ha of harvested cropland (US Department of Agriculture, National Agricultural Statistics Service, 2014). Fernandez-Cornejo et al. (2014) estimated that nearly $12 billion was spent on pesticides in US agriculture in 2008. A wide range of pesticides are utilized on the agricultural landscape to minimize crop losses due to insects, disease and weeds. In 2012, 40.8 million ha of agricultural land was treated with insecticides, while 115.5 million ha was treated with herbicides (US Department of Agriculture, National Agricultural Statistics Service, 2014). Even with improved management practices, the proximity of agricultural land to water resources such as rivers or lakes often results in their contamination by pesticide runoff following storm or irrigation events. Such occasions have the potential to harm downstream aquatic resources if not properly mitigated.

Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine], a broadleaf herbicide, was first registered for use

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in the US in 1959. Since 2001, atrazine has been the second most used pesticide active ingredient in the US, trailing only glyphosate (Grube et al., 2011). In 2008 alone, 29.9 million kg of atrazine active ingredient was applied on 21 of the main US crops (Fernandez-Cornejo et al., 2014). Albright et al. (2013) suggested that local waterways surrounding agricultural lands may exceed the maximum contaminant level of 3 μg/L, as recommended by the US EPA, for drinking water resources. Although trends of atrazine concentrations over the last two decades have generally declined in both surface and ground water (Stone et al., 2014; Toccalino et al., 2014), frequent detection, even at low levels, can potentially produce deleterious aquatic effects (Davies et al., 1994; Detenbeck et al., 1996).

S-metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl-*N*-[(2S)-1-methoxy-2-propanyl] acetamide] is a pre-emergent broadleaf herbicide used on crops such as corn, soybeans, and cotton. In 2001, between 9.1 and 10.9 million kg of metolachlor active ingredient were applied in the US, ranking it as the 9th most applied pesticide. By 2008, this value had increased to 13.6–15.9 million kg of metolachlor active ingredient applied annually in the US, moving the herbicide into the 4th most applied pesticide (Grube et al., 2011). Metolachlor is one of the most frequently detected pesticides in both agricultural and mixed land use watersheds, with usage and concentration trends turning upward from 2001 to 2010 (Stone et al., 2014). The drinking water health advisory level for metolachlor is 0.525 mg/L (Rivard, 2003).

Diazinon [O,O-diethyl-O-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate], an organophosphate (OP) insecticide, is part of a class of compounds originally designed to replace the more persistent organochlorine insecticides. Use of diazinon has declined over 80% between 2001 and 2008, with under 500,000 kg of active ingredient applied in 2008, yet it remains the 8th most commonly used OP insecticide (Grube et al., 2011). Between 1992 and 2001, some 45% of urban streams exceeded the diazinon aquatic-life benchmark (Stone et al., 2014). Concomitant with a decline in usage has been less frequent detections in streams, especially those in urban watersheds (Stone et al., 2014). Although diazinon's use is declining in the US, toxicity problems still arise, specifically in agricultural areas in California (de Vlaming et al., 2004).

Phytoremediation is a common management practice which emphasizes the use of vegetation to remediate pollutants. In agricultural settings, phytoremediation is utilized through such practices as riparian buffers, stiff-grass hedges, constructed wetlands, and vegetated drainage ditches. Numerous studies have reported on the positive effects of vegetation in decreasing pollutant loads, especially pesticides (Moore et al., 2007; Cejudo-Espinosa et al., 2009; Arora et al., 2010; Zhang et al., 2010; Anderson et al., 2011; Murphy and Coats, 2011; Elsaesser et al., 2011; Locke et al., 2011; Albright et al., 2013). In the current study, three rooted, emergent macrophytes were chosen for evaluation of pesticide remediation: *Typha latifolia* L. (broad-leaved cattail), *Sparganium americanum* Nutt. (American bur-reed), and *Leersia oryzoides* (L.) Sw. (rice cutgrass). *Typha latifolia* is ubiquitous within all 50 United States, as well as almost all Canada provinces (USDA, 2013). It can tolerate perennial flooding, drawdown cycles, reduced soil conditions, and moderate salinity (Stevens and Hoag, 2006). *Sparganium americanum* is distributed as far northwest as Manitoba, southwest as Texas, northeast as parts of Newfoundland and Labrador, and southeast as Florida (USDA, 2013). This perennial, obligate plant can reach up to three meters in height, prefers a pH range of 4.9–7.3, has no salinity tolerance, and prefers full sun. Leaves may be stiff and erect, but they have the ability to bend and float on the surface of the water during flowing water situations (Favorite, 2006). *Leersia oryzoides* is located in the contiguous 48 states, eight Canadian provinces, and warmer parts of Europe (Darris and Bartow, 2008; USDA, 2013). Commonly called rice cutgrass or sicklegrass, *L. oryzoides* is a popular species for erosion control in ditches. This perennial forms dense colonies, spreads *via* underground rhizomes, and is common near streams, ponds, ditches, and canals. *Leersia oryzoides* can tolerate seasonal or permanent flooding, while preferring a pH of 5.1–8.8 (Darris and Bartow, 2008). The objective of the current study was to examine *T. latifolia, S. americanum,* and *L. oryzoides* for their individual ability to mitigate atrazine, S-metolachlor, and diazinon loads in simulated storm runoff water.

1. Materials and methods

Mesocosms were constructed using twelve, 379 L high density polyethylene oval containers (1.3 m length × 0.71 m width × 0.61 m height) by layering 16 cm of Lexington silt loam atop a base of 22 cm of sand (Fig. 1) (Target study pesticides were below detection for both the silt loam and sand used in the study). Each mesocosm was then planted with monocultures of one of three, rooted, emergent aquatic plant species: cutgrass (*Leersia oryzoides* L. Sw.), broad-leaf cattail (*Typha latifolia* L.) and American bur-reed (*Sparganium americanum* Nutt.). Each plant species was represented by three replicate mesocosms, with three unvegetated mesocosms serving as controls. All plants and sediment used in the study were collected from the University of Mississippi Field Station (UMFS), Abbeville, MS. Areas used for plant collection have received no pesticide application in the last 30 years since the University took ownership of the property in 1985. An

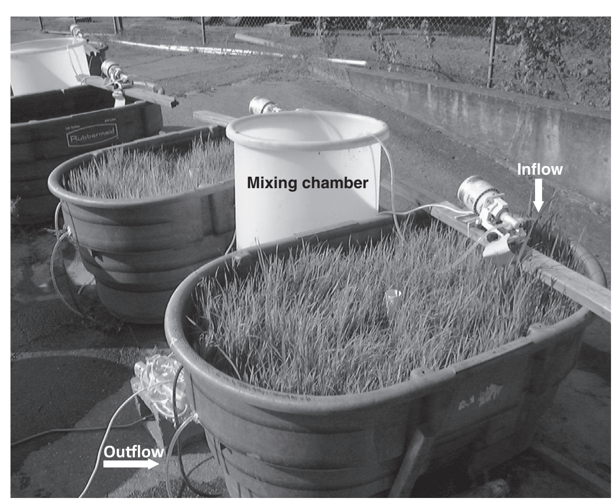

Fig. 1 – Mesocosm setup with pesticide mixing chamber, piston pump for pesticide delivery, inflow tubing, and outflow tubing for collection of sample.