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Atrazine fate and transport within the coastal zone in southeastern Puerto Rico

Thomas L. Potter [a,*], David D. Bosch [a], Angel Dieppa [b], David R. Whitall [c], Timothy C. Strickland [a]

[a] USDA-ARS, Southeast Watershed Laboratory, Tifton, GA 31793, United States
[b] Jobos Bay National Estuarine Research Reserve, Aguirre, PR 00704, United States
[c] NOAA National Centers for Coastal Ocean Science, Silver Spring, MD 20910, United States

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ABSTRACT

Agrichemical transport to coastal waters may have adverse ecological impact. This work examined atrazine fate and transport in a field adjacent to Puerto Rico's Jobos Bay National Estuarine Research Reserve. The herbicide's use was linked to residue detection in shallow groundwater and movement toward the estuary; however, data indicated that transport via this pathway was small. In contrast, surface runoff as tropical storm systems moved through the area appeared to have high potential for atrazine transport. In this case, transport to the estuary was limited by runoff event timing relative to atrazine application and very rapid atrazine dissipation (DT_{50} = 1–3 days) in field soil. Soil incubation studies showed that accelerated degradation conditions had developed in the field due to repeated atrazine treatment. To improve weed management, atrazine replacement with other herbicide(s) is recommended. Use of products that have greater soil persistence may increase runoff risk.

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1. Introduction

Pollution from land-based sources is a serious threat to coastal water quality and ecosystem health worldwide (Halpern et al., 2008). Within the Caribbean basin, agriculture is often identified as a major contaminant source in coastal waters; however, few studies have established direct links between crop production and coastal water quality impairment (Rawlins et al., 1998; Taylor et al., 2003; UNEP-CEP, 2012). In order to address environmental concerns and design effective management practices that minimize impacts, investigations are needed that delineate contaminant types, sources, and transport pathways (Wilkinson and Brodie, 2011; Brodie et al., 2012). Within coastal zones, pollutant transport pathways include surface runoff and leaching of soluble contaminants to shallow groundwater followed by seepage into Bays and wetlands. Wet and dry atmospheric deposition may also contribute pesticides and nutrients to these environments (Valiela and Bowen, 2002; Alegria and Shaw, 1999).

Our work focused on atrazine (6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1, 3, 5-triazine-2,4-diamine) an herbicide commonly used in corn (*Zea mays*), sorghum (*Sorghum bicolor*), and sugarcane (*Saccharum officinarum*) production. Due to concerns about the frequent detection of atrazine and selected degradates in surface and groundwater, the European Union (EU) withdrew permission for atrazine use in EU states in 2004; however, intensive atrazine use continues in North and South America and Asia (Pathak and Dikshit, 2012). Widespread atrazine use has also contributed to intense scientific interest in the herbicide's environmental fate, transport, and residue analysis, and potential for adverse impact in coastal ecosystems. Recent notable work includes detection of residues in Australia's Great Barrier Reef Ecosystem at levels that have potential for negative ecological impact (Shaw et al., 2010; Smith et al., 2012; Lewis et al., 2012). These studies and related work have indicated that Caribbean and other tropical coastal ecosystems may be adversely impacted by atrazine use in coastal zones (Bell and Duke, 2005; Jones, 2005; Gao et al., 2011; Magnusson et al., 2010; Pinckney et al., 2002; Shaw et al., 2010).

We addressed this concern during a 2.5-year investigation of atrazine fate and transport during its use on a 100-ha irrigated farm field adjacent to Jobos Bay National Estuarine Research Reserve (JBNERR) on Puerto Rico's southeast coast. The study was part of a USDA Conservation Effects Assessment Project (CEAP) Special Emphasis Watershed project (Zitello et al., 2008). Baseline biological and sediment quality assessments within Jobos Bay and Bay water quality monitoring conducted for CEAP were described in a recent report (Whitall et al., 2011). During the study potential pesticide wet deposition was assessed and will be reported elsewhere. Findings showed that the potential for atrazine transport to the Bay via this pathway was small (Potter unpublished results).

* Corresponding author. Tel.: +1 229 386 7073; fax: +1 229 3867294.
E-mail address: Tom.Potter@ars.usda.gov (T.L. Potter).

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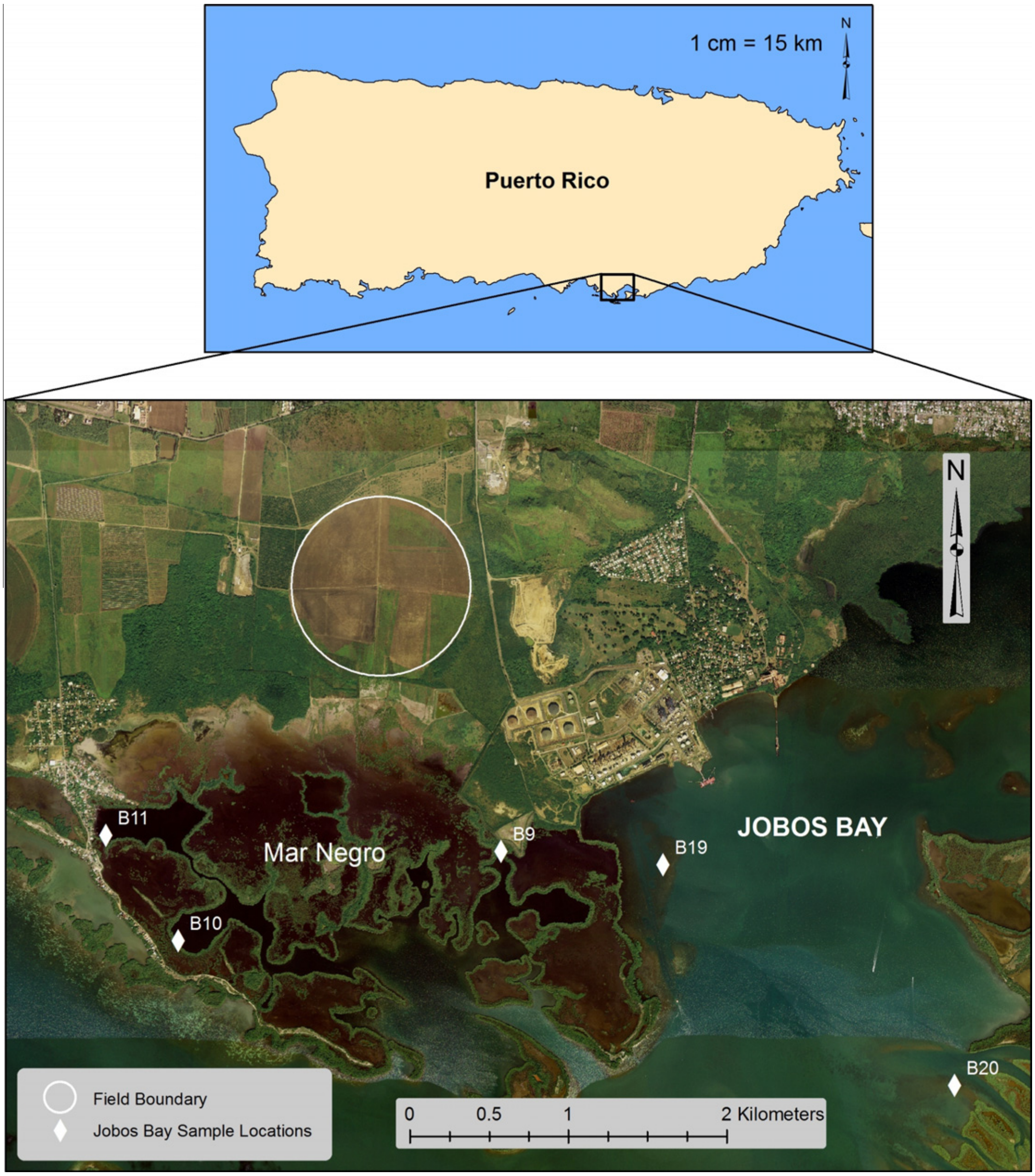

Fig. 1. Location of farm field and Jobos Bay sample collection locations. Base maps (USGS, 2012a,b).

2. Materials and methods

2.1. Study site

JBNERR is located on Puerto Rico's southeast coast (Fig. 1). Field et al. (2008) provide a comprehensive ecological profile of the JBNERR and surrounding areas. A farm field adjacent to the JBNERR "Mar Negro" mangrove-wetlands forest complex was selected for the study (Fig. 1). The field was chosen due its close proximity to JBNERR and long standing concerns about agrichemical transport from the field to the estuary. Land between the field and Mar Negro, a distance of about 160 m, is managed as a mixed grass and dry-land forest buffer (Fig. 2). Three drainage ditches cross the buffer area and create a hydrologic connection between the field and Mar Negro's tidal flats (Fig. 2). Two soil series, Cartagena and Poceña clays, cover about 90% of the field. These somewhat poorly to moderately well drained vertisols which were formed in alluvium and marine sediment, have 40–45% clay in surface horizons, 0–2% slopes, and pH 7.5–8.2 (USDA-NRCS, 2012). Climatic conditions are semiarid-tropical with mean annual temperature 27 °C and rainfall 1000 mm with rainfall dominated by tropical storm events during the wet season that occurs from May through November (Kuniansky and Rodríguez, 2010).

2.2. Management

The field was divided into four quadrants of about 25 ha each. During 2008–2009, corn and sorghum were grown rotationally for silage. Irrigation was provided by a center pivot system using water from a well about 0.5 km NW (Fig. 2) that draws from the Salinas fan alluvial aquifer (Kuniansky and Rodríguez, 2010). Quadrants were planted in sequence so that one could be harvested every 3 months. All tillage and herbicide applications occurred prior to planting. Farm records showed that atrazine was the pesticide applied in greatest amount exceeding all other on-farm pesticide use by 2-fold. In 20 separate applications between February 2008 and November 2009, 360 kg of atrazine were applied (Fig. 3). After failure of the irrigation system in December 2009, pesticide applications stopped.