A New Approach to Modeling Potential Pesticide Aquatic Exposure in Urban Residential Environments: Development of an Urban Model Scenario and Modeling System

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PYRETHROID WORKING GROUP

Introduction

The complexity of modeling pesticide fate and transport in an urban residential environment is a result of both the heterogeneity of the urban residential landscape, and variability in how pesticides are applied to different use sites within this environment. Current regulatory residential pesticide exposure model scenarios are based on agricultural models designed to simulate relatively homogeneous field conditions and uniform application practices and therefore fail to reflect this complexity. A novel approach linking US EPA's SWMM runoff model and the AGRO-2014 receiving water model was developed to allow the conservative representation of a more accurate conceptual model of residential pesticide use, fate, and transport. The approach incorporates independent parameterization of pesticide application and wash-off characteristics for multiple use sites, including lawns/landscape areas, foundation perimeters, driveways, and patios/walkways. The resulting model scenario, validated with site-specific monitoring data, represents a high vulnerability urban residential watershed (near the 90th percentile housing density nationally), making it well-suited for use in regulatory aquatic exposure modeling.

Conceptual Model of Residential Outdoor Pesticide Use

Residential Use Sites

- Outdoor pesticide applications in residential environments are more complex than pesticide applications in agricultural settings.
- Applications can occur at different rates and frequency for common residential use sites.
- Primary use sites explicitly accounted for include::
  - o Building foundation perimeters (impervious and pervious areas), including garage door and walls
  - o Patios and walkways (away from the building)
  - o Driveways (away from the garage door and wall)
  - o Lawns/landscape areas
- Applications to hard surfaces are responsible for the vast majority of pesticide off-site movement (Davidson et al., 2014), with the top of the driveway (routinely treated and directly connected to the sewer system) most vulnerable.

Figure 1. Residential Use Sites.

Required Use Site Application Model Inputs, Conceptual Example

- **The fraction of neighborhood households receiving outdoor insecticide treatments:** In Figure 2, six out of the eight households in the neighborhood receive outdoor insecticide treatments, equal to a fraction treated of 0.75.
- **The fraction of use sites treated with each active ingredient:** For those households that receive an outdoor insecticide treatment, which use sites receive applications. In Figure 2, bifenthrin is applied to building foundation perimeters for two of the six households that receive insecticide treatments, resulting in a fraction of building foundation perimeters treated with bifenthrin of 0.33.
- **The seasonal frequency of applications made to each use site:** This characteristic describes how often and when applications to use sites are made. For example, a lawn may receive one application in the spring, two applications in the summer, and one application in the fall.
- **The percentage of a use site's surface area that is treated:** This application characteristic is shown schematically in Figure 3. This figure shows a driveway (away from the garage door) that has been split into treated and untreated sections. In this example, 20% of the driveway surface area (away from the garage door) is treated and 80% of the driveway surface area is untreated.

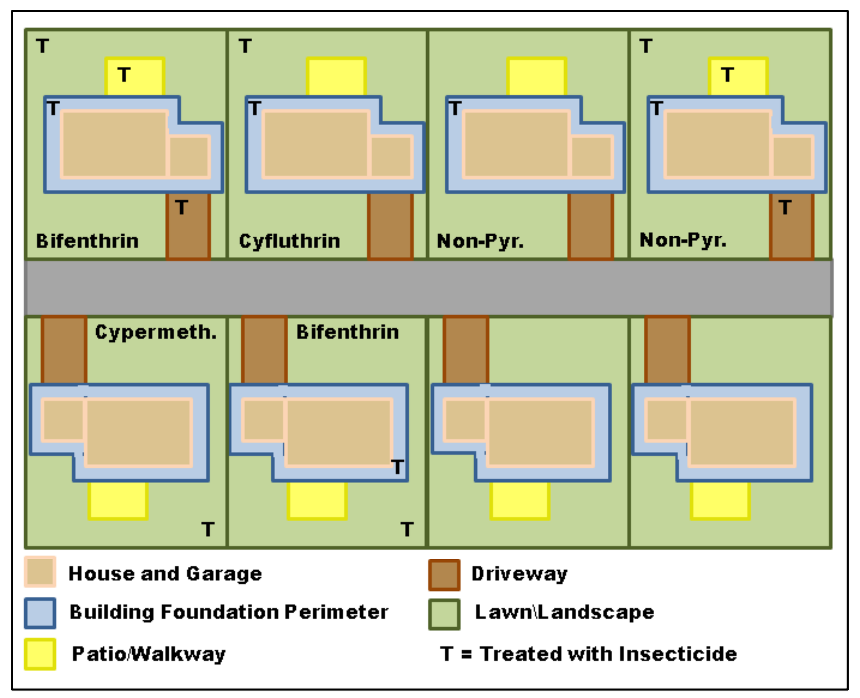

Figure 2. Neighborhood Fraction of Households and Types of Use Sites Treated.

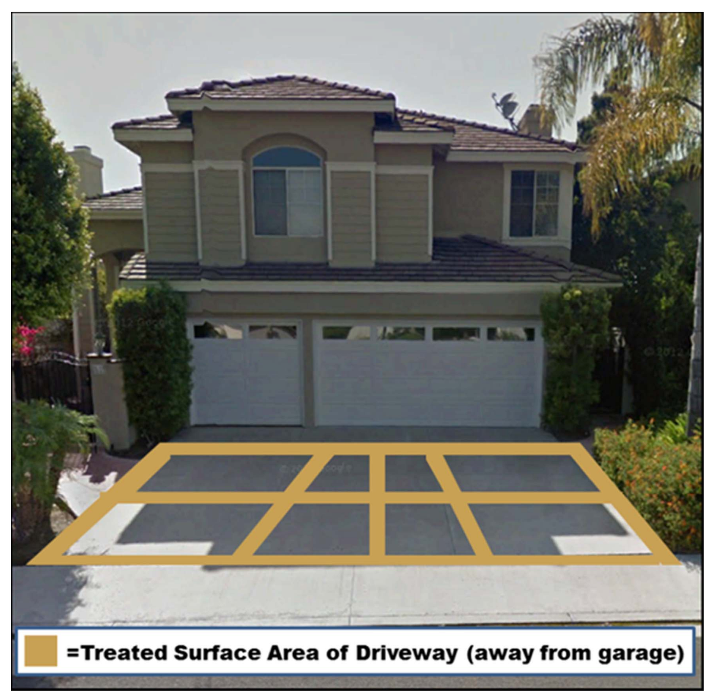

Figure 3. Percentage of a Use Site Surface Area Treated.

Model Development

Scenario Site Selection

- Aliso Viejo, Orange County, CA
- Part of CA DPR / UC Riverside monitoring program (Oki and Haver, 2011)
- Drainage area: 67.2 acres
- 307 homes, 4.6 units/acre.
- A national, single family residential census block housing density analysis showed the site to represent the 88th %-ile

Geographic Region	Single Family Residential Census Blocks	Census Blocks with Lower Density than Aliso Viejo (%)
California	417,767	72.3
Northwest (WA, OR)	224,042	85.4
North Central (IL,WI, MO)	693,821	88.0
Northeast (VT, NH, MA, CT, RI)	208,756	89.1
Mid-Atlantic (NJ, DE, MD, DC)	222,414	77.9
Southeast (FL, GA)	512,269	87.7
South Central (TX)	504,509	91.9
Contiguous US	6,279,464	87.9

Figure 4. Location of Urban Scenario Neighborhood.

Model Selection

- **Runoff Model:** Storm Water Management Model (SWMM) (US EPA, 2011)
  - o Watershed scale, urban/residential water quantity and quality model used by many EPA divisions
  - o Able to model multiple pervious and impervious surface types (lawn, driveway, etc.)
- **Receiving Water Model:** AGRO-2014 (Padilla and Winchell, 2013)
  - o Based on Quantitative Water, Air, Sediment Interaction (QWASI) Fugacity model (Mackay, 2001)
  - o Explicit simulation of sediment dynamics, important for high Koc pesticides

Model Structure and Assumptions

- Aliso Viejo neighborhood was spatially delineated from aerial imagery.
- Particular attention was given to impervious use sites:
  - o Lower driveway
  - o Upper driveway (within 5 ft. of garage)
  - o Garage door
  - o Impervious surfaces within 5-ft of foundation perimeter
  - o Patios/walkways away from building
- Impervious areas near lawns (within 1.5 ft.) receive irrigation
- A fraction of impervious surfaces (other than driveway) flow into adjacent lawns.
- Each landscape element in the model can be divided into portions receiving pyrethroid applications and portions not receiving applications.
- Further division can be made to allow multiple application frequencies (e.g., every 6 weeks, and every 12 weeks).
- The watershed is divided into "sub-watersheds", allowing for more accurate routing and variability in pyrethroid application timing.

Figure 5. Spatial Delineation of Aliso Viejo Neighborhood Landscape Elements

Washoff Model

- The standard SWMM model provides three washoff options (exponential equation, rating curve, event mean concentration), which are all a function of flow rate.
- Research by Luo et al. (2014) described a theoretically based washoff algorithm specifically designed for predicting pesticide washoff from hard surfaces.
- The Luo washoff method was tested using Pathway ID study field data (Davidson et al., 2014), and then incorporated into the SWMM model code base.
- A SWMM model was developed to simulate washoff from both driveway and lawn surfaces.
- Calibration of washoff sought to match observed total washoff and daily washoff distribution.
- The Pathway ID washoff calibration served as the basis for the urban model scenario.

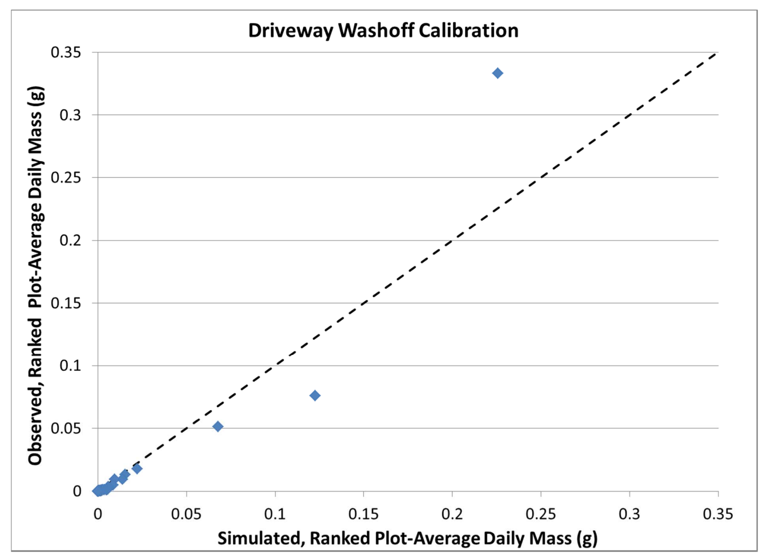

Figure 6. Calibration of Luo Algorithm to Observed Washoff from Driveway.

Model Calibration of SWMM Scenario

Hydrology

- Daily and hourly flow calibration from 1 year of monitoring

Flow Time Step	Total Flow Bias	R^2	Nash Sutcliffe
Daily	0.98	0.85	0.83
Hourly	0.98	0.64	0.57

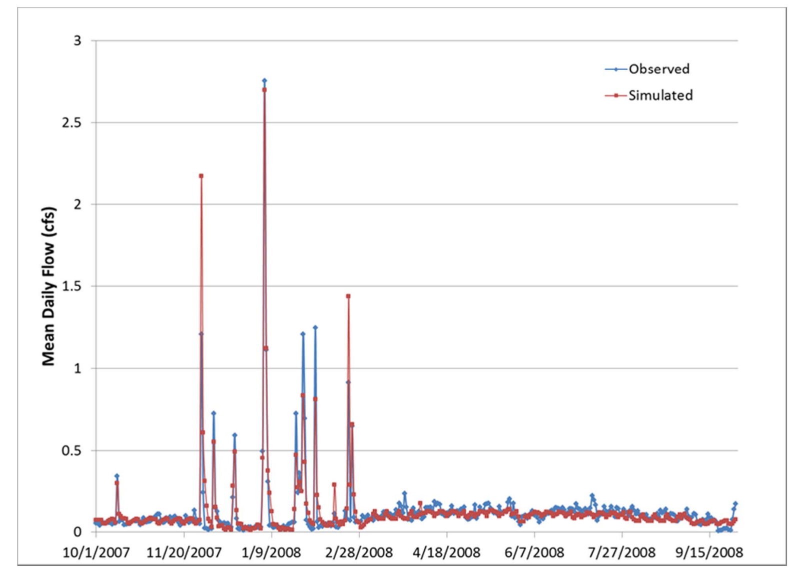

Figure 7. Daily Flow Calibration from Stormwater Outfall.

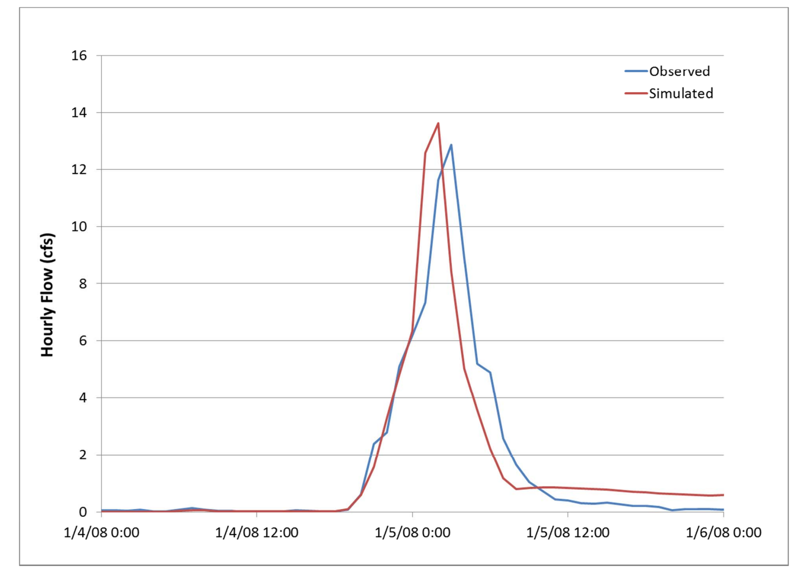

Figure 8. Hourly Flow Calibration from Stormwater Outfall, 1 Storm Event.

Pesticide

- 30 bifenthrin total water samples (storm and non-storm) from 1-year of Aliso Viejo outfall monitoring
- Both daily average concentration and cumulative total mass load from the outfall were compared
- Overall, very good agreement between the SWMM predictions and the monitoring data

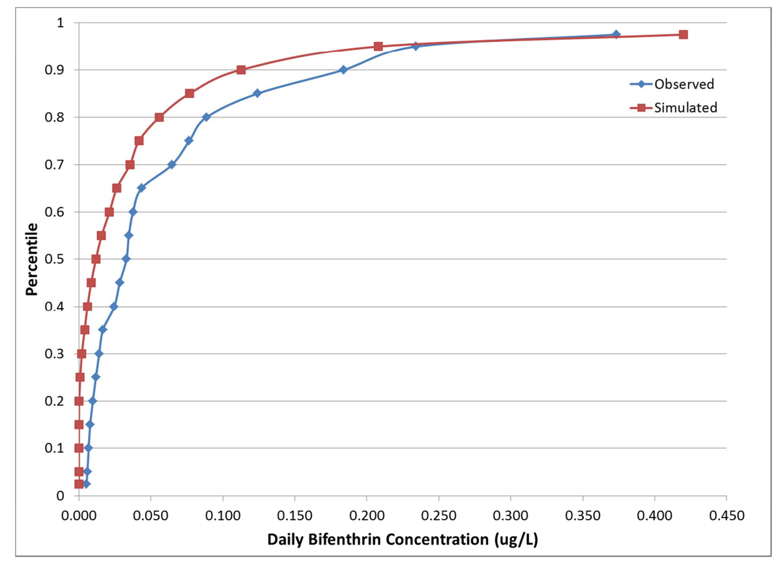

Figure 9. Calibration of Cumulative Distribution of Daily Bifenthrin Concentration

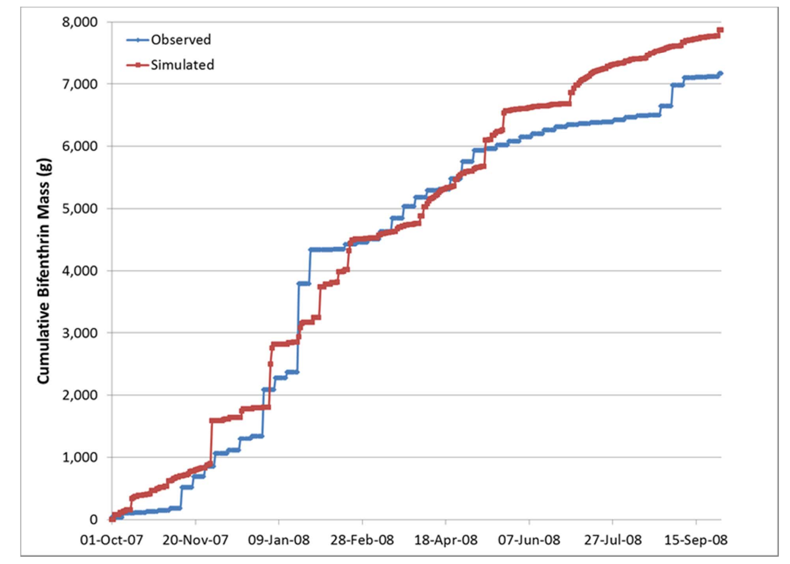

Figure 10. Calibration of Cumulative Bifenthrin Mass Load

SWMM-AGRO Interface

- SWMM-AGRO is a graphical user interface (GUI) that seamlessly integrates EPA's Stormwater Management Model (SWMM) with the AGRO-2014 receiving water model
- Capabilities of the SWMM-AGRO interface include:
  - o Running SWMM-AGRO simulations for 8 regional scenario parameterizations and 7 pyrethroids
  - o Modification of scenario assumptions regarding pyrethroid use extent
  - o Creation of customized application schedules (rates and dates)
  - o Store pesticide environmental fate properties
  - o Running simulations with and without irrigation

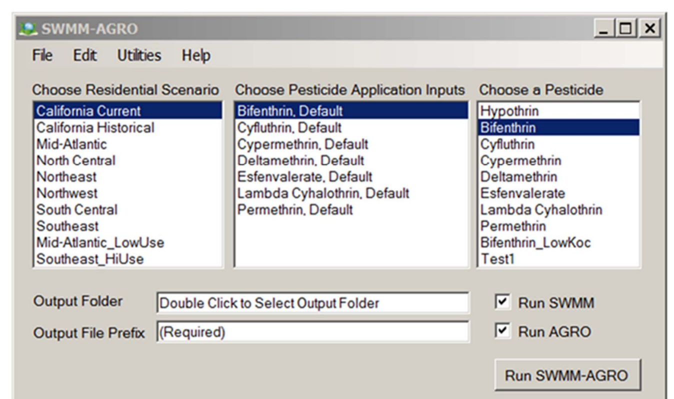

Figure 11. SWMM-AGRO, Main Interface.

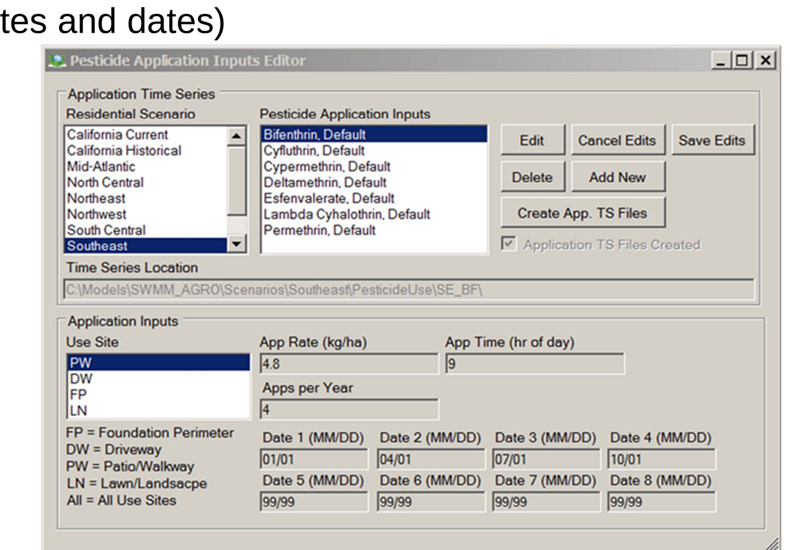

Figure 12. SWMM-AGRO, Application Time-Series Editor.

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Oki, L.; Haver, D. 2011. Evaluating Best Management Practices (BMPs) Effectiveness to Reduce Volumes of Runoff and Improve the Quality of Runoff from Urban Environments. Agreement Number 04-231-550-03. Urban Environments Final Report, California Water Resources Board, Sacramento, CA.