Development of a California-Based Receiving Waterbody Model for Pesticide Registration Evaluation

Yina Xie, Yuzhou Luo, Nan Singhasemanon, Kean S. Goh
Surface Water Protection Program, Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA 95812

Abstract

The California Department of Pesticide Regulation's Surface Water Protection Program (SWPP) is improving the modeling system to evaluate pesticide products submitted for registration in California. A receiving waterbody model that is based on California conditions would be a key component of this system and is currently under development by SWPP. The model development includes two stages – 1) review of modeling theory, and 2) development of California-relevant receiving waterbody scenarios. The Variable Volume Water Model (VVWM), developed by the US Environmental Protection Agency (USEPA), was found to be a promising receiving waterbody model for the regulatory use by SWPP. To inform the development of California-based scenarios, tests were conducted to assess the performance of VVWM and the modeling scenarios suggested by the USEPA. Results are presented here.

Introduction

A receiving waterbody model is a crucial component in evaluating the environmental risk of pesticides. The model accounts for different physical, chemical, and microbial processes associated with the transport and fate of pesticides in the receiving waterbody, and estimates environmental concentrations for pesticide exposure characterizations. An important category of the receiving waterbody model is the regulatory model, which is developed and configured to simulate the standard receiving waterbodies and provide conservative estimation of the Estimated Environmental Concentration (EEC). Currently, this component has not been fully incorporated into California's pesticide registration evaluation. SWPP is working on the consistent employment of the regulatory model and specifically via the exclusive use of receiving waterbody simulations based on California conditions.

First, theoretical review was conducted to establish the simulation engine. Three regulatory receiving waterbody models – VVWM by the USEPA, AGRO-2014 by the Stone Environmental, Inc., and Toxic Substances in Surface Waters (TOXSWA) by the European Forum for the Coordination of Pesticide Fate Models and Their Use (FOCUS) workgroup – were examined. Xie (2016) concluded that VVWM was the most promising model for use by SWPP for pesticide registration evaluation. In VVWM, a receiving waterbody is conceptually represented by a compartmental system that consists of the water compartment and the sediment compartment (Figure 1, Young, 2014).

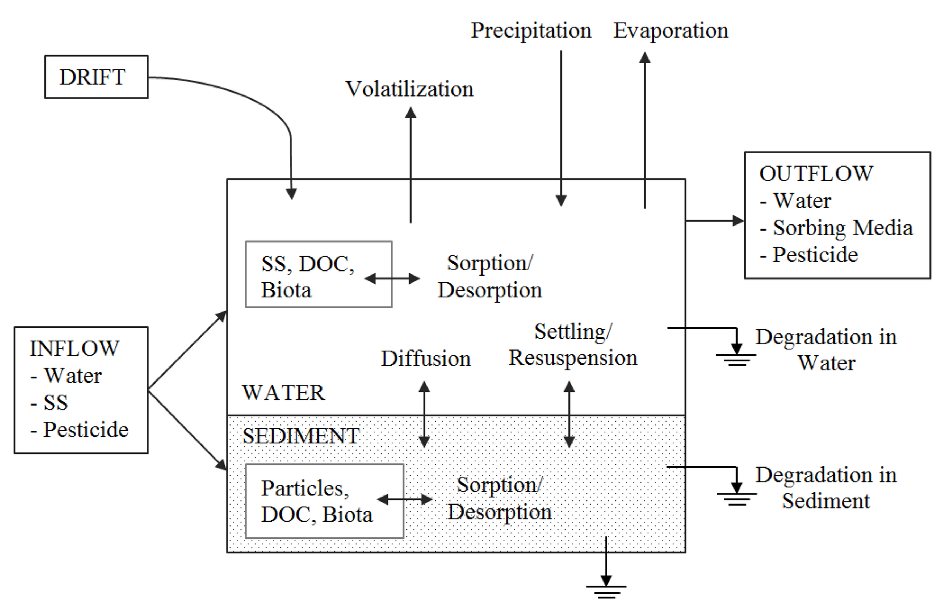

Figure 1. Conceptual model, adapted from Figure 1 in Young (2014)

Second, given the fact that the existing standard receiving waterbody scenarios suggested by the USEPA for nationwide use may not address California conditions, specific scenarios are being developed.

Model Test

Input parameters required by VVWM to construct a receiving waterbody can be grouped into four categories:

A. *Parameters related to dimension*, including field area, water area, water depth, and cropped area fraction (fraction of field treated with pesticides). The USEPA (2016) suggested that these parameters could be grouped into one overall parameter – the Drainage Area Normalized to Capacity (DANC), which is referred to as the ratio of treated field area to water volume. By examining the modeling theory, we found that the level of EECs resulted from runoff was primarily controlled by the relative size of the treated field and the waterbody (i.e., DANC), instead of the actual sizes. Note that a fixed water depth is required for the relationship to hold true.
B. *Parameters related to flow regime*, including w/ vs. w/o flowthrough, flow averaging day (i.e., number of days that are used to average the influent water flow) and base flow rate if w/ flowthrough is true.
C. *Parameters governing pesticide distribution between and within the two compartments*, including the overall water-sediment mass transfer coefficient and PRBEN (i.e., the percentage of sediment-sorbed pesticides in the inflow that is directly delivered to the sediment compartment).
D. *Other parameters* that describe the physiochemical property of the waterbody.

The USEPA (2016) indicated that parameters in groups A, B, and C were key to the watershed/waterbody setup. A sensitivity test was conducted to assess how these parameters affect the prediction of EECs in water column (Cww) and in pore water (Cdw). The test was based on three pesticide application scenarios – dormant spray of chlorpyrifos on almonds (S1), fall weed control spray of simazine on strawberries (S2), and foliar spray of bifenthrin on lettuce (S3). EECs estimated from the USEPA farm pond scenario was set as baseline. Spray drift efficiency was set to zero to eliminate the impacts of spray drift on EECs. Results are illustrated in Figure 2.

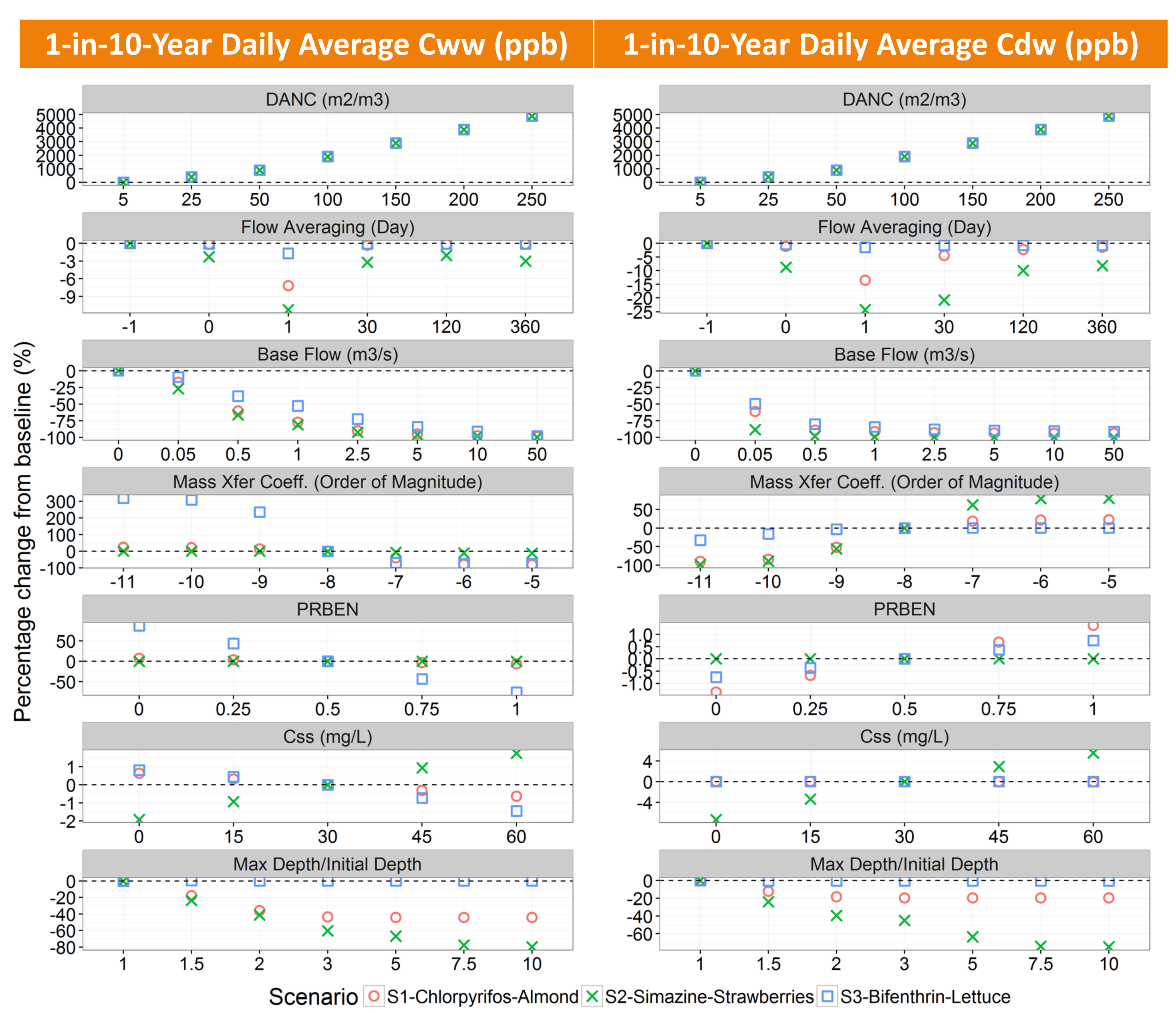

Figure 2. Sensitivity test (VVWM)

The USEPA Standard Receiving Waterbodies

The USEPA OPP Farm Pond has been used as the standard receiving waterbody for pesticide evaluation in the US. Recently, the USEPA (2016) proposed several new waterbodies, named aquatic bins, for aquatic risk assessments. Table 1 shows the setup of the USEPA receiving waterbodies.

Table 1. Setup of the USEPA OPP farm pond and aquatic bins for California (HUC18)

Parameter	Unit	OPP Pond	Bin2-Low Flow	Bin3-Median Flow	Bin4-High Flow	Bin5-Low Static	Bin6-Median Static	Bin7-High Static
DANC	m2/m3	5	1830	2318	3175	107	40	20
Field Area	m2	1E+05	1.34E+05	3.44E+08	6.45E+10	10.68	3.97E+03	3.97E+05
Water Area	m2	1E+04	7.32E+02	1.48E+05	1.02E+07	0.1	100	1E+04
Initial Depth	m	2	0.1	1	2	1	1	2
Max Depth	m	2	0.1	1	2	1	1	2
Waterbody Type [a]	-	4	5	5	5	4	4	4
Flow Averaging	day	0	1	1	1	0	0	0
Base Flow	m3/s		0.0005	0.5	50	0	0	0
Mass Xfer Coeff.	m/s	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}
PRBEN	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Water Column SS	mg/L	30	30	30	30	30	30	30
Drift Eff. - Aerial	-	0.05	0.437	0.32	0.167	0.469	0.297	0.093
Drift Eff. - Ground	-	0.01	0.62	0.294	0.089	0.778	0.252	0.042
Drift Eff. - Airblast	-	0.03	0.372	0.219	0.064	0.418	0.192	0.027

[a] Code for waterbody type: 4 = Constant water volume with no flowthrough; 5 = Constant water volume with flowthrough.

The performance of the USEPA receiving waterbodies was tested in terms of their ability to capture the worst case in California. Five pesticides with top agricultural use and high toxicity were included. Pesticide application methods were obtained from the USEPA label review, which summarized the max application rate for each label-allowed crop. The greatest EECs among the tested applications were obtained to represent the worst-case application for each pesticide. Figure 3 shows the results. The simulated 1-in-10-year daily average EECs (Sim.) were compared to the average of the top-3 concentrations observed in California's agricultural areas (Obs.), with natural log conversion. EECs predicted from the USEPA farm pond were the smallest among the bins and about 1–10 times greater than the observed values.

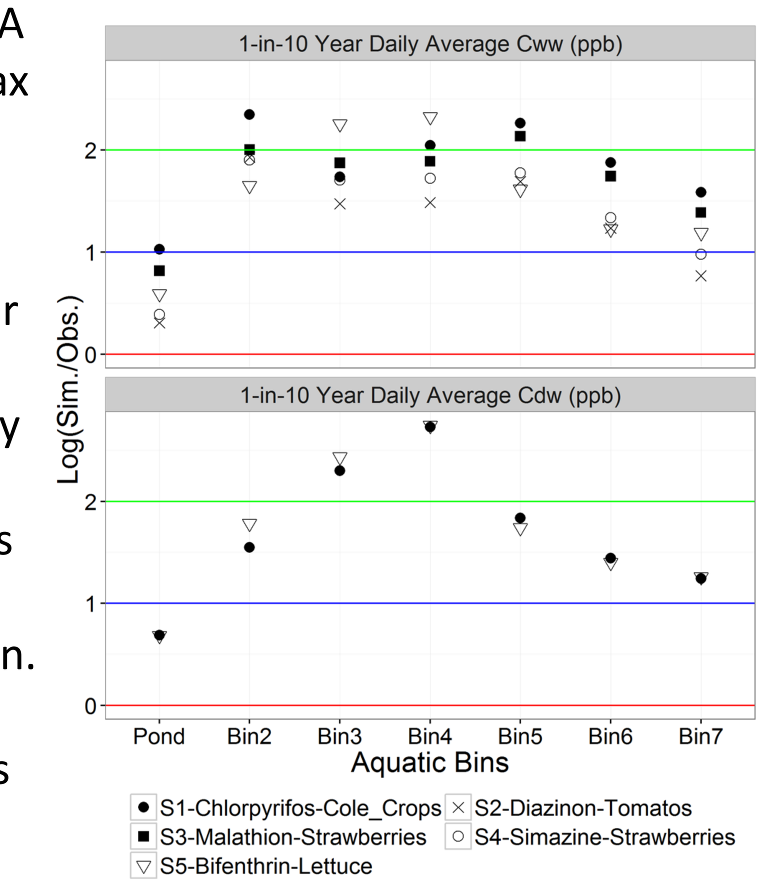

Figure 3. Performance of the USEPA standard receiving waterbodies

Summary

Sensitivity test on watershed/waterbody parameters shows that:

1. For a given water depth, the relative size of the treated field and the waterbody (i.e., DANC) controls the level of EECs predicted by the model. DANC is proportional to the 1-in-10-year daily average EECs.
2. Flow, water depth, PRBEN, and mass xfer coeff. are important factors.

Test on the USEPA standard receiving waterbodies shows that the USEPA farm pond is generally able to provide reasonable conservative estimates of EECs for agricultural uses in California. Fine-tuning is needed for a more precise California-based setup.

References

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