EVALUATION OF A RICE HERBICIDE TRANSPORT MODEL

By
Richard S. Breuer
Environmental Research Scientist

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STATE OF CALIFORNIA
Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring and Pest Management Branch
1220 N Street, Sacramento, California 95814

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ABSTRACT

A simple model of transport of the rice herbicide molinate was tested by running it with known application amount data and measuring Sacramento River flow from each of four years (1985-1988). The calculated concentrations were compared to measured concentrations. Regression of measured concentration on modelled concentration gave slopes which ranged from 0.35 to 0.56 and were all significantly different from 1.0 ($p<0.05$). Intercepts ranged from 0.41 to 0.74 ppb and were significantly different from 0.0 ($p<0.05$) except for 1985. The uniform underprediction of concentrations by the model was probably due to the discharge value, which was originally calculated based on only a single year of data and which, if recalculated, might provide estimates closer to measured values.

ACKNOWLEDGMENTS

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INTRODUCTION

The herbicide molinate (Ordram®) is discharged into Sacramento Valley waterways following application to rice fields (Finlayson and Lew 1983; Cornacchia et al. 1984). Because of concern over impacts to the agricultural environment and drinking water supply, multiple state and local agencies have been involved in monitoring residues and reducing concentrations through regulatory programs.

Efforts to understand the relationship between field dissipation and the diluting effects of water in agricultural drains and the Sacramento River led to the development of a model by the California State Water Resources Control Board (CSWRCB). The goal was to create a predictive tool for evaluating the effect of regulatory programs on reducing herbicide concentrations (CSWRCB 1990). The model uses total molinate applied per day, river flow rates, and chemical degradation values to predict daily concentrations in the Sacramento River at the city of Sacramento. The model was completed, but the evaluation and validation were never finished.

In this study, the predictive capabilities of the CSWRCB model were evaluated using monitoring and application data from the years 1985 through 1988.

MATERIALS AND METHODS

The model was written with Dbase III® (Ashton-Tate, Torance, California), database software that runs in the MS-DOS environment. Other studies have shown that the use of higher level program applications such as spreadsheet and graphic packages can provide a useful environment for both modeling and results evaluation (Southwood et al. 1989). For this study, the program was run in Dbase III, and the results analyzed with Excel® (Microsoft, Seattle, Washington) spreadsheet and SigmaPlot® (Jandel Scientific, Corte Madera, California) graphing software.

The model is summarized by the following formula:

$$G = (A \times B \times C \times D \times E / F)$$

Where:

G = ug/L (ppb) of molinate estimated in the Sacramento River at Sacramento for a given date.

A = Total kg applied = total acres treated x 4 lb per acre x 0.454 kg/lb.

B = % applied/d. The average percentage of molinate applied for a given date based on past years (1977 -1985), converted to a fraction.

C = % discharged = weighted mass discharge percentage from the three main agricultural rice drains converted to a fraction. Based on measurements taken in 1985, 2% of the total amount of molinate applied moved through the agricultural drains into the river base on a 8 d hold of molinate in the rice paddy.

D = fraction of molinate remaining after dissipation past eight days

$= e^{x}$, $x = (4.605 - ([\text{hold} - 8] \times [.693/\text{half}]))$

Hold = days of holding period in rice field.

Half = Number of days for half the amount of molinate present to dissipate (t 1/2). A t1/2 of 4 days was selected for this evaluation (Ross and Sava 1986; Soderquist et al. 1977; Scardachi et al. 1987).

E = ug/L (ppb) conversion factor

$=(408.56 \text{ day } f^{3} \text{ ug/sec L kg})$

F = Sacramento River Flow at Sacramento (ft^3/sec)

Users of the model select daily flow data from a year that resembles the current year.

For this evaluation, several of the input values were based on data from the four study years instead of historical data and averages as described above. Inputs and outputs were estimated as daily averages and totals. The actual daily application amount (based on the rate of 4 lb/a treated) was used to calculate percent per day applied (A and B). Also, actual daily flow rates (F) were used for each year.

The model treats the entire northern Sacramento valley rice basin as one large rice field, with an average transport time of 6 d between time of release from the rice field and the chemical being detected at Sacramento. Date concentration measured at Sacramento = ([Date applied in rice field] + [holding period in field] + 6 d)

Measured concentrations were regressed on modeled concentrations to see how well the values agreed. A two-tailed t test with alpha =.05 for slope and intercept was used for measuring whether the slope and intercept of the regression line was significantly different than 1 and 0 respectively.

RESULTS AND DISCUSSION

Modeled versus measured concentrations for each of the four years are shown in Figure 1. The regression plots are shown in Figure 2. Except for the 1985 intercept, all slopes and intercepts were significantly different from 1 and 0 respectively. This indicates the model output was significantly different than the measured values. The average slope over the four years was 0.44, indicating predicted concentrations were more than double the measured concentrations.

This is also reflected in calculated mass transport at Sacramento. Mass transport is the total mass of herbicide that passes by Sacramento during the rice growing season. Modeled mass transport for the four years averaged 64 percent higher than actual mass transport.

The main factor causing higher modeled concentration amounts is the 2% discharge value (C) calculated in 1985 from the measured output of the three main agricultural drains which are the only source of molinate in the river. This is reflected in the higher slope value for the 1985 regression analysis, and the intercept not being significantly different than 0. Yet, the 1985 measured values of concentrations were still significantly lower. The discharge value (C) needs to be recalculated, based on the results of this evaluation.

Variability in daily model output is caused by several factors. Temperature is a major factor in molinate dissipation, and the model does not take into consideration fluctuations of temperature and the effects on half life. The model treats the entire rice area region as one big field, and daily percentage of application is not differentiated between the various rice growing basins. This causes differences in transportation time, since they physical location of each rice field that is a component of the daily total is of varying distances from Sacramento.

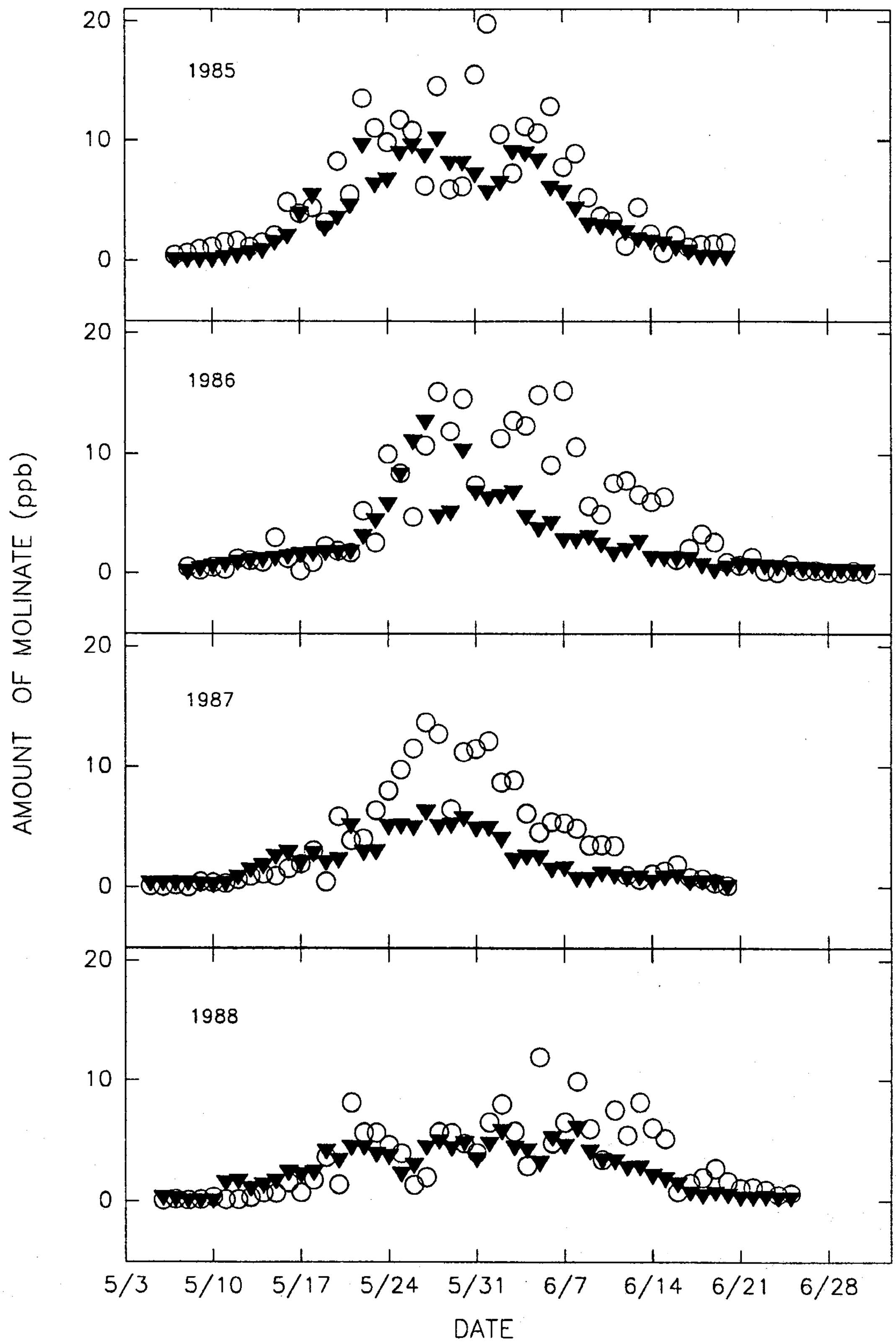

FIGURE 1. Comparison of modeled (○) versus measured (▼) molinate concentrations in the Sacramento River for the years 1985 to 1988

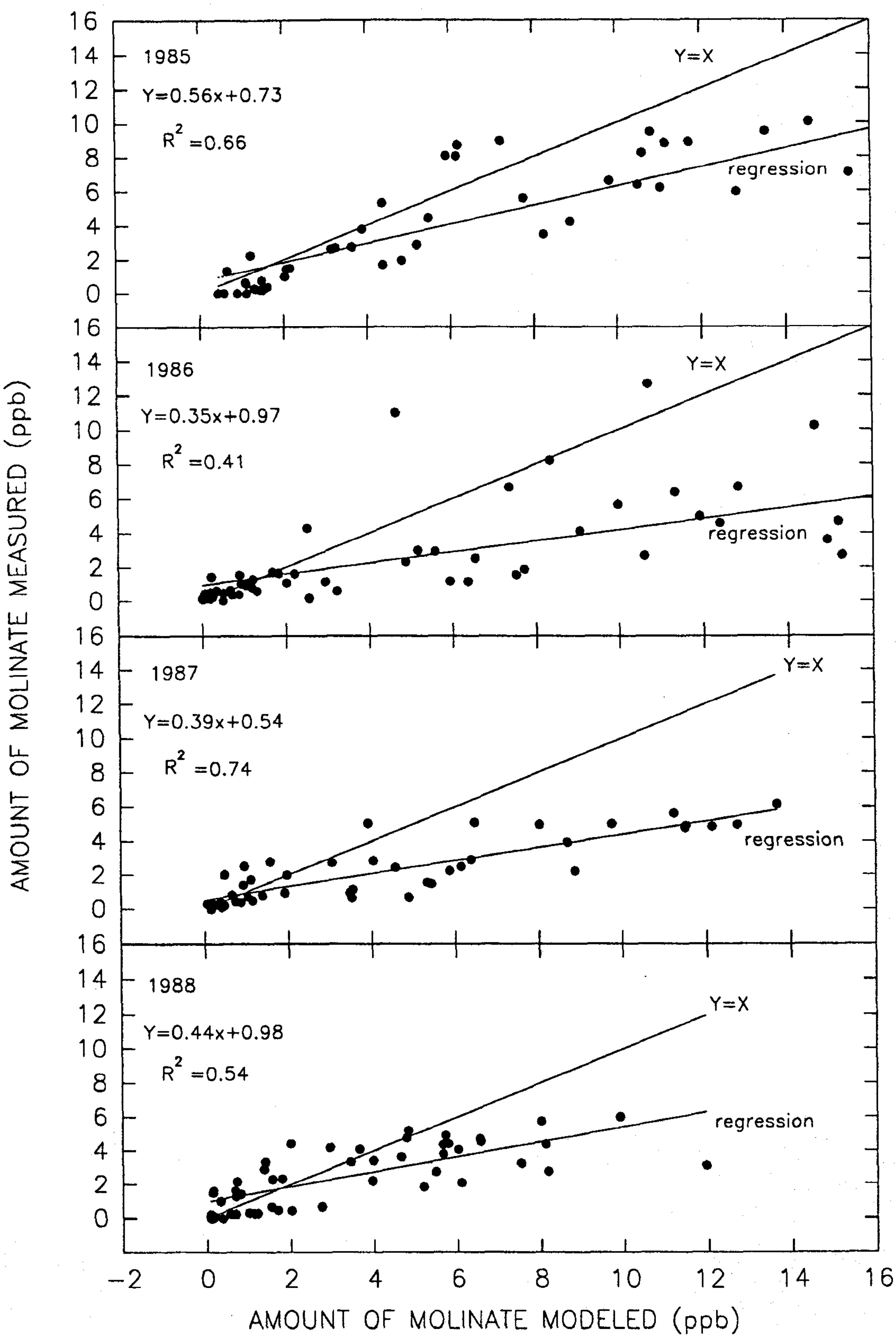

Figure 2. Regression analysis of measured versus modeled (•) molinate concentrations in the Sacramento River for the years 1985 to 1988

The model also assumes that on the day of release from the rice field, the entire amount of remaining molinate leaves the field and enters the drainage system, which is unlikely. Officials encourage a slow release to encourage further dissipation (Scardaci et al. 1987). Concentration values from laboratory analysis of monitoring samples are possible sources of error, though an independent quality control study showed good correlation between various labs analyzing molinate samples (Mischke 1983).

Suggestions for improving the model include dividing the rice regions into modules that are modeled based on daily applications within the drainage basin. Half-life calculations could be customized on a daily basis within each of these basins by developing a relationship between change in half-life and fluctuations in daily temperature. Transport time would also be more accurate, since the individual basins would be modeled, and the sum of the basin outputs reflect total concentrations at Sacramento.

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