Research *You Can Use*

Modeling Pesticide Runoff from Turf

Can computer modeling help protect the environment?

BY DOUGLAS A. HAITH

PHOTO BY DR. KEVIN ARMBRUST, UNIV. OF GA.

Modeling pesticide runoff can be useful in evaluating the potential for applied chemicals to migrate to surrounding surface waters.

Turf professionals recognize that improperly applied chemicals used to control turfgrass pests can be harmful to the plants and animals that live in and around the ponds, streams, and lakes surrounding golf courses and other grassed areas. Indeed, care is taken to prevent contamination of these waterways from spills, rinse water, or inadvertent applications. However, it may be difficult to control pollution from another route: the runoff of pesticides caused by rainstorms and melting snow. When water from these natural events flows off the turf, it may carry the pesticides with it to surface water.

UNDERSTANDING RUNOFF

The considerable water-holding capacities of the components of turf systems (i.e., verdure, thatch, and soil) limit water runoff from all but the most severe weather events, unless the system is already saturated. Also, the extensive adsorption by turf organic matter tends to bind pesticides to the turf even when water runoff does occur. Nevertheless, the threat of pollution cannot be discounted. Sampling of waters near golf courses has detected many turf pesticides, and it is likely that at least some, if not most, of those chemicals were transported in runoff.

Whether the pollution is large or small, the ultimate concern must be prevention, or at least management to control it. But such management requires information. Which chemicals are most likely to run off? What practices reduce or eliminate runoff? If chemicals do move from turf to waterways, what will their impacts be?

Surface water pollution from pesticide runoff can be a result of significant rainfall occurring soon (e.g., less than 24 hours) after the chemical application. Successful turf managers are always cognizant of current and forecasted weather conditions, so in well-managed turf, this may rarely occur. This limits our ability to draw conclusions regarding the extent of runoff from field experiments. Although it is possible to experimentally create the extreme precipitation conditions that produce significant pesticide runoff, the effort required cannot account for all turf chemicals or the broad range of weather and site conditions encountered in the field.

COMPUTER MODELING

Environmental engineers rely on mathematical models, or equations, to predict water pollution. The models are usually referred to as *fate and transport* models because they predict the movement and ultimate deposition of water contaminants.

Until recently, no fate and transport models were available specifically for turf. Rather, researchers and consultants resorted to models that were developed for agricultural crops. It was reasoned that the interaction of chemicals, plants, and soils is similar for turf and field crops. However, when pesticide runoff values were calculated from these models for turf areas and compared with actual measurements taken in the field, large discrepancies became apparent. These discrepancies arose because of fundamental differences in the ways that plants and soil influence pesticide behavior in crops and turf.

Agricultural models typically view chemical runoff losses as originating in the surface layer of soil. Chemicals are washed off crop foliage and added to the soil surface, where they subsequently contribute to runoff. However, given the dense vegetation of turfgrass foliage and thatch, most surface losses from turf occur directly from vegetation. Runoff losses from turf soils play a relatively minor role. From the point of view of pesticide behavior, field crops are *soil* systems and turf is a *plant* system.

DEVELOPMENT OF A PESTICIDE RUNOFF MODEL FOR TURF

The United States Golf Association has sponsored research on runoff modeling for several years at Cornell University. Early on, we thought that agricultural models could be adapted for turfgrass

Using computer modeling to evaluate the potential for pesticide runoff can aid in protecting golf course water features.

systems, but this approach was eventually abandoned for the development of a new model based on the unique characteristics of turf. This model is called TurfPQ and is available (including the user's manual) by request (dah13@cornell.edu).

As the model was developed, it was important that it be practical and that it function as a credible tool for turf professionals and consultants. This meant that the input data required for the model be readily available, and software should be easy to run on desktop computers. It also meant that the model would be subjected to extensive field testing to determine if its predictions were accurate.

Field testing is a critical aspect of model development. A fate and transport model is nothing more than a set of mathematical equations translated into computer code. The equations may or may not accurately reflect reality. Until a model is tested, it is just an elaborate hypothesis. To test the model, field experiments are designed to measure pesticide runoff from turf systems subject to controlled applications of water and chemicals. The fate and transport model is then run with appropriate input parameters corresponding to the experiments. The runoff values predicted by the model are compared with the observed or measured pesticide runoff. If the measured values and the predicted values are relatively close, the model can be accepted as a reasonable tool for predicting pesticide runoff.

TESTING THE MODEL

TurfPQ was tested using published plot runoff data for 52 runoff events in four states, involving three soil groups, four turfgrass species (bermudagrass, creeping bentgrass, tall fescue, and perennial ryegrass), and six pesticides. The outcome of this testing is shown in the accompanying graph, which compares observations and model predictions. Each data point in the figure corresponds to the model prediction and observed pesticide runoff for a single runoff event. Points, or events, lying on the line y' = y represent perfect model performance (i.e., model values are exactly equal to observations). Points above the line indicate over-prediction by the model (i.e., predicted pesticide runoff is higher than the measured value). Events lying under the line are under-predicted.

Most of the events are relatively close to the line, indicating that TurfPQ predictions are fairly close to the actual measured pesticide runoff. There are exceptions, however. For two of the events, the model predicts pesticide runoff of approximately 20% of that applied, but the actual values were closer to 10%. On average, model results are about 50% larger than the measured values, which, by model prediction standards, can be considered very good.

USE OF TurfPQ FOR RISK ANALYSIS

The value of a model such as TurfPQ is that it can rapidly evaluate or simulate the effects of widely differing chemicals, weather, management, and site conditions. When run with extensive multi-year weather records, simulations can provide long-term estimates of pesticide runoff.

As an example, we used TurfPQ to simulate runoff of two common turf fungicides, chlorothalonil (Daconil) and iprodione (Chipco 26019) from bentgrass fairways in Boston, Mass; Philadelphia, Pa.; and Rochester, N.Y. One-hundred-year records of daily precipitation and temperature were produced for each of these locations. The simulations produced 100-year daily records of three variables: water runoff, pesticide runoff, and pesticide concentration in runoff.

These simulations allowed us to estimate quantities of pesticide that could reach nearby surface waters. Comparing those predicted runoff values with the LC_{50} for *Daphnia magna* (water flea) and rainbow trout gives an indication of the environmental risk posed to surrounding surface waters. LC_{50} is the chemical concentration which kills 50% of the test species over a 48- or 96-hour period.

Even allowing for the fact that TurfPQ predictions tend to be 50% larger than actual values, it is hard to escape the conclusions that the current use of chlorothalonil and iprodione may pose significant water quality risks. However, it may be possible to mitigate these risks by modifying application schedules and amounts. One of the virtues of models such as TurfPQ is that such modifications can be easily evaluated.

A NEW ERA IN ENVIRONMENTAL ASSESSMENT

Concerns for the environmental impacts of turf chemicals seem to have gone through three phases: problem awareness, understanding, and solution. During the first phase, which largely overlapped the 1980s, we became aware of the potential for water pollution from the extensive use of turf chemicals. Reactions from environmental groups and turf managers were sometimes extreme, and it is probably safe to say that many of the concerns were based more on emotion than fact.

During the 1990s, a great deal of scientific research on the issue was published, and the results of experiments and monitoring brought us to a much better understanding of the problem. We are now in the third, or problem-solving phase. With mathematical models such as TurfPQ to evaluate potential for pesticide runoff, we now have the tools to evaluate alternative chemicals and management strategies to help safeguard the environment.

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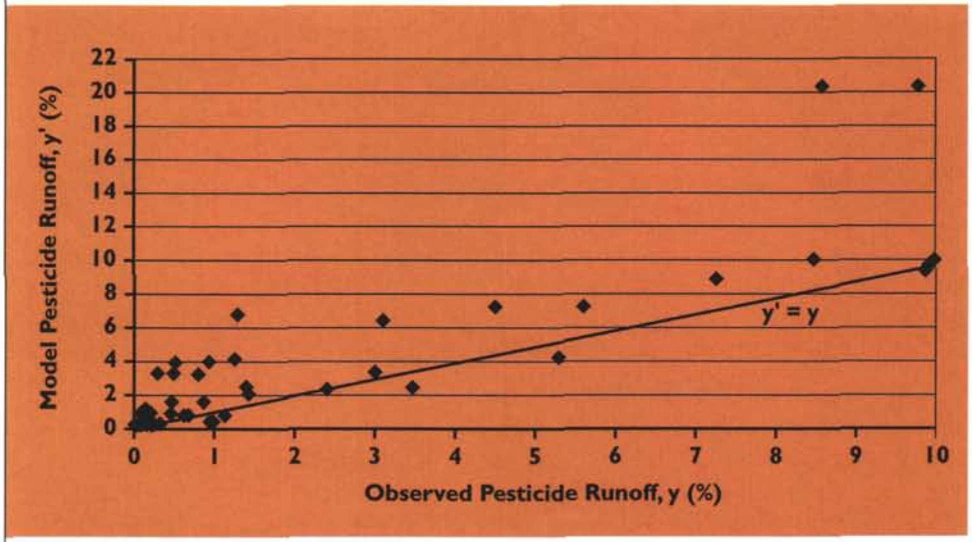

Comparison of TurfPQ model pesticide runoff estimates with observed values. Points on the line represent perfect prediction by the model of the observed runoff. Points above the line indicate over-prediction (model overestimated actual runoff), and those below the line indicate under-prediction (model underestimated actual runoff).

Mean Pesticide Runoff (%)

Pesticide	Number of Events	TurfPQ Model Prediction	Observed
2,4-D	7	8.3	4.3
Chlorpyrifos	3	2.9	0.5
Diazinon	6	0.3	0.7
Dicamba	7	4.0	3.6
Dithiopyr	18	1.2	0.3
Mecoprop	11	4.2	3.7
Overall Mean	52	3.2	2.1

Comparison of observed and TurfPQ modeled pesticide runoff for six pesticides.