Underlying Assumptions for EPA's Pesticide Exposure and Risk Assessment Models

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ABSTRACT

EPA conducts a series of different exposure assessments that support pesticide risk assessments for terrestrial and aquatic organisms. In some cases, the exposure and risk assessment (RQs) are contained within the same model, while in other cases the exposure assessments are conducted using a separate model. Several key assumptions underlie each of these exposure assessments that are critical to understanding and interpreting the resulting risk assessments. Therefore, it is critical to recognize and understand the implications of these underlying assumptions when interpreting pesticide risk assessments. However, there is often little to no discussion of these underlying assumptions, and the impact of these assumptions on the resulting risk assessment, which can easily result in misinterpretation of the risk assessment. It is important to recognize that these assumptions are conservative, supporting the role of EPA's standard risk assessments as screening-level assessments. This presentation discusses some of the key assumptions underlying several of EPA's pesticide exposure and risk assessment models, and the impacts of these assumptions on the resulting risk assessments. The models discussed include T-REX and T-HERPS, used to evaluate potential exposure and risks to birds and small mammals, and herpitiles, PRZM-EXAMS and GENEEC, used to evaluate potential exposure of freshwater and estuarine-marine organisms, and TERRPLANT, used to evaluate potential effects on non-target plants. Key assumptions underlying T-REX include assumptions concerning the available diets, the feed ingestion rates of different sizes of birds and mammals, the percentage of the diet obtained from a treated area, residue concentrations on feed items, and the exposure duration required for toxicological effects. For the aquatic models, some key assumptions include assumptions concerning water body depth, water flow through the modeled water body, the spatial relationship between the receiving water body and the pesticide-treated area, wind direction during application, mixing and distribution of pesticide loading in the receiving water body, and the time to response for non-target organisms. The TERRPLANT model includes assumptions concerning drift of aerial and ground applications, the relationship between size of the treated area and sensitive areas, and runoff to nearby untreated areas. Overall, these underlying assumptions have a significant impact on the model results. Changes to these underlying assumptions can significantly impact resulting risk assessments so recognizing and understanding these assumptions is key to properly interpreting the model results.

INTRODUCTION

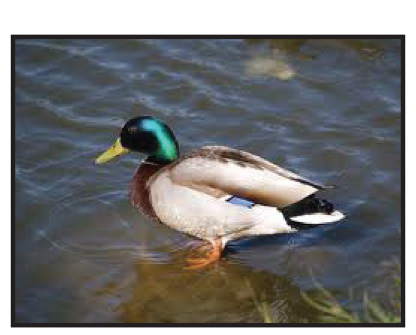
A key aspect of EPA's regulation of pesticides are its environmental exposure modeling and risk assessments. EPA primarily uses exposure modeling techniques to estimate pesticide concentrations in environmental media, such as surface water, groundwater, and soil. EPA also uses models for estimating pesticide concentrations in/on feed items for terrestrial organisms. These estimated environmental concentrations (EECs) in media or feed items are then used in conjunction with acute and longer-term (sub-chronic, chronic) toxicity data for non-target terrestrial and aquatic animals and plants to estimate potential effects from labeled uses of pesticides.

All of the models used by EPA are considered screening-level models that, consistent with being screening-level models, incorporate several conservative assumptions. Risk quotients (RQs) are calculated either directly by the models, or separately by the risk assessor using EECs generated by the models. These RQs represent an initial, conservative cut on potential risks to different taxa of non-target animals and plants. Oftentimes, the screening level results indicate that one or more of EPA's levels of concern (LOCs) are exceeded. Therefore, it is often necessary to refine the screening level assessments to address these potential non-target organism risk concerns. There are options for refining the results of these screening level assessments if uses of a product are found to exceed EPA's levels of concern for adverse effects on either endangered or non-endangered non-target organisms. However, understanding the underlying assumptions of the models used for non-target organism pesticide exposure estimates and risk assessments is essential for correctly interpreting the model EECs and RQs, as well as for refining an assessment to address possible non-target organism risk issues.

MODELS OVERVIEW

Aquatic Models

EPA uses two different models for estimating aquatic concentrations – GENEEC and PRZM-EXAMS. Both of these models provide EECs only, with risk quotients (RQs) then being calculated separately by the risk assessor. Both models provide EECs for multiple time periods, ranging from immediately after application (0 hours) to up to a year following application. For example, PRZM-EXAMS provides EECs for time 0 (immediately after application), 4 days after application, 21 days after application, 60 days after application, 90 days after application, and one year after application. Thus, the output for both models is a series of EECs; the longer-term EECs are time-weighted average EECs for these longer time periods.



For estimating risks to aquatic organisms, the appropriate EEC (acute or longer-term EEC) is then paired with the applicable acute or longer-term toxicity endpoint in separate RQ calculations for estimating acute and chronic risks to freshwater fish, estuarine fish, freshwater pelagic invertebrates, estuarine pelagic and benthic invertebrates, non-target vascular aquatic plants, and several different algal taxa. When multiple toxicity values are available for a taxonomic group, such as freshwater fish (e.g., trout and bluegill data), the toxicity endpoint for the most sensitive species is used for estimating risks to this taxonomic group.

PRZM-EXAMS also provides EECs for pore water, which EPA uses for evaluating potential acute and chronic risks to sediment-dwelling organisms, such as amphipods.

The receiving water body for both PRZM-EXAMS and GENEEC is a small shallow pond. The same receiving water body (pond) is used for estimating potential risks to freshwater and estuarine organisms. This receiving water body is 2 m deep and has a 1–hectare (ha) surface area. The watershed that drains into this pond is a 10 hectare field.

EPA uses additional aquatic models for estimating human dietary exposures to pesticide residues in surface and groundwater sources of drinking water. For surface water, EPA uses the Index Reservoir version of PRZM-EXAMS. The Index Reservoir model in PRZM-EXAMS is similar to the surface water pond model, but utilizes a different receiving water body (a small reservoir).

For residues in groundwater, EPA has recently developed the PRZM-Groundwater model. EPA also has the SciGrow model to estimate pesticide concentrations in groundwater. This model is a linear regression model for pesticide applications in vulnerable soils that is based on application rate, soil adsorption coefficient (Koc), and the pesticide degradation rate in soil.

Terrestrial Models

Birds and Mammals

EPA relies on the T-REX model for assessments of potential risks to birds and mammals. The T-REX model calculates both EECs and RQs for different size classes of birds and mammals. While EECs are provided as part of the model output, the primary outputs of the model are acute and chronic RQs for three different size classes of birds and mammals. These size classes include 15 g, 35 g, and 1000 g for mammals, and 20 g, 100 g, and 1000 g for birds.

The T-REX model focuses on potential risks from ingestion of feed items containing pesticide residues by birds and mammals. Depending on whether dietary EECs and RQs or acute oral EECs and RQs are calculated, the T-REX model utilizes either four or five general categories of feed items. These include:

- Short grass
- Long/tall grass
- Broadleaf plants
- Seeds, fruits, and pods
- Arthropods/insects

The EECs for these different categories of feed items are based on the Hoerger and Kenaga nomogram, as modified by EPA (Fletcher et al, 1994). The EPA nomogram relates pesticide concentrations on the different feed item categories to pesticide application rates. The nomogram provides residue unit doses (RUDS) for a 1 lb a.i./A application rate. The RUDs are then multiplied by the application rate of the pesticide being evaluated to estimate residue concentrations on these general categories of feed items for specific uses of the pesticide.

Reptiles and Amphibians

EPA uses a similar model, T-HERPS, for estimating EECs and RQs for herpitiles (amphibians and reptiles). As with T-REX, the T-HERPS model estimates EECs and calculated RQs for three different size classes of herpitiles (1.4 g, 37 g, and 238 g). Instead of a separate arthropods/insects feed item category, the T-HERPS model includes "small" insects with the broadleaf plant feed item category and "large" insects with the seeds, fruits, and pods category. T-HERPS also includes three additional categories of feed items for herpitiles:

- Small herbivore mammals
- Small insectivore mammals
- Small terrestrial phase amphibians

The T-HERPS model calculates pesticide residues in these prey items by estimating the residue residues that these prey items would ingest.

Terrestrial Plants

For estimating exposure and risks to non-target terrestrial plants, EPA uses the TerrPlant model. This model evaluates three different potential exposure routes for non-target plants. These include:

- Exposure through sheet erosion
- Exposure through channelized runoff
- Exposure through spray drift

Both the sheet erosion and channelized runoff exposure scenarios include a spray drift component, so these scenarios evaluate potential exposure of non-target terrestrial plants through both runoff and spray drift, while the spray drift assessment focuses only on non-target exposure through drift.
EECs estimated for the sheet erosion and channelized runoff scenarios are compared to the results of seedling emergence testing, while EECs for the spray drift scenario are compared to vegetative vigor testing results to estimate potential risks to non-target terrestrial plants.
EECs are calculated for a single application of the pesticide, consistent with the design of the non-target terrestrial plant phytotoxicity tests.

KEY ASSUMPTIONS OF AQUATIC MODELS

It is important to conceptualize the two aquatic exposure models. In both the GENEEC and PRZM-EXAMS models, the 1 ha, 2 m deep pond is assumed to be completely surrounded by the treated 10 ha field. Key assumptions include:

- There is no buffer area between the treated field and the pond; the treated field directly abuts the pond;
- The receiving pond is downwind from the treated field, so drift goes directly to the pond;
- Instantaneous mixing of the pesticide occurs throughout the water body;
- There is no water flow into or out of the pond;
- The volume of the pond does not change with runoff loading;
- Default spray drift values are used (currently1% for ground applications, 3% for airblast applications, 5% for aerial applications, although AgDrift estimates may be used in the near future);
- EPA uses upper 90th percentile confidence limits for pesticide degradation rates;
- Currently, buffer zones can be modeled for spray drift loading but not for runoff loading;
- Pesticide application timing is not adjusted for weather events;
- Upper-end slope values are used.

The PRZM-EXAMS model provides acute and longer-term EECs for 20 to 30 years of weather inputs, generally ranging from 1961 to 1990. The amounts and timing of rainfall are different for each year modeled, resulting in a range of EECs. For RQ calculations, EPA uses the upper 10th percentile acute and longer-term EECs from PRZM-EXAMS for aquatic animal and plant risk assessments.

KEY ASSUMPTIONS OF T-REX AND T-HERPS

The T-REX and T-HERPS models are used to evaluate potential risks to birds, mammals, reptiles, and amphibians. Key assumptions include:

- Animals obtain 100% of their daily food from treated areas;
- Animals forage on the same treated area daily;
- Animals consume a diet that consists only of feed items from one of the available feed item categories (e.g., animals ingest only short grass, or only broadleaf plants, etc.);
- Assessments are primarily made based on upper-end residue estimates
- In T-HERPS (and older versions of T-REX) residues on arthropod/insect type feed items are assumed to be the same as those on broadleaf plants ("small insects") or seeds, fruits, and pods ("large insects");
- RQs are calculated for EECs for the day of application (single application) or the last day of a multiple application scenario;
- Residues from multiple applications are assumed to build up linearly, with feed items always receiving either the upper-end estimated residues or the typical estimated residues;
- Chronic effects are assumed to occur from a single feeding, so acute and chronic (longer-term) EECs are assumed to be the same.

Many of the calculations in T-REX and T-HERPS are built into these spreadsheet models, so it is difficult to re-run the model with adjustments to these key assumptions. The easiest refinement to evaluate is running the model using typical residue estimates rather than upper-bound estimates, since this is a model output option.

KEY ASSUMPTIONS OF TERRPLANT

Effects on non-target terrestrial plants are evaluated using the TERRPLANT model. Key assumptions include:

- For the sheet erosion scenario, runoff from 1 treated acre is assumed to move to an adjacent untreated 1 acre plot;
- The channelized runoff scenario is assumed to represent a low-lying, wetland area that receives runoff;
- For the channelized runoff scenario, pesticide from 10 treated acres are assumed to run off to a nearby 1 acre plot;
- The runoff fraction depends on the pesticide's water solubility – if the water solubility is <10 ppm, the runoff fraction is 1% of applied pesticide; if the water solubility is 10 – 100 ppm, the runoff fraction is 2% of applied; if the water solubility is >100 ppm, the runoff fraction is 5% of applied; soil Koc is not used to estimate the runoff fraction;
- Incorporation depths of up to 6 inches reduce the estimated runoff fraction;
- There is no degradation component when modeling runoff;
- For spray drift, the non-target plants are assumed to be directly downwind from the treated area;
- Default drift values are 1% for ground applications and 5% for airblast or aerial applications.

EECs for sheet erosion and channelized runoff are compared to seedling emergence results. The EC25 is used as the toxicity endpoint for evaluating potential effects on non-endangered terrestrial plants, while the NOEL is used as the toxicity endpoint for evaluating potential effects on endangered terrestrial plants. The EEC for spray drift is compared to vegetative vigor testing results, again with the EC25 value being used as the toxicity endpoint for evaluating potential effects on non-endangered terrestrial plants and the NOEL being used as the toxicity endpoint for evaluating potential effects on endangered species. Results for the most sensitive monocot and dicot species are used for risk assessments.

DISCUSSION AND CONCLUSIONS

EPA conducts environmental modeling to estimate exposures of aquatic and terrestrial organisms to pesticide products. The exposure estimates (EECs) generated by these models are compared to acute and chronic toxicity data to estimate acute and chronic risks to representative aquatic and terrestrial taxa. Representative taxa include freshwater and estuarine fish and aquatic invertebrates, birds, mammals, reptiles, amphibians, aquatic plants, and terrestrial plants.

The GENEEC and PRZM-EXAMS models are used to develop acute and longer-term aquatic EECs for estimating risks to aquatic organisms, including aquatic plants. T-REX and T-HERPS are used to estimate both EECs and RQs for birds, mammals, reptiles, and amphibians. Acute and chronic EECs generated by T-REX and T-HERPS are the same because of the assumption that chronic effects can occur with a single exposure. TerrPlant is used to develop both runoff and spray drift EECs for evaluating potential effects on non-target terrestrial plants.

In all of the risk assessments, toxicity values for the most sensitive species are used to estimate potential risks of pesticides to these different groups of non-target species.

All of these models are considered screening-level models. Each of the models that EPA relies on has several key underlying assumptions that significantly affect the output of the model. It is essential to recognize and understand the underlying assumptions of these models to correctly interpret the EECs developed by the models and the RQs that are calculated using these EECs. In many cases, the initial screening level assessment results in one or more of EPA's levels of concern being exceeded, which indicates that the screening-level risk assessment should be refined. Therefore, it is also important to understand the underlying assumptions of these models for refining the risk assessment.