REDUCTION OF UNCERTAINTY IN CHRONIC AVIAN RISK ASSESSMENTS FOR GRANULAR ORGANOPHOSPHATE-NEMATICIDES BY THE USE OF FIELD EXPOSURE DATA AND PROBABILISTIC RISK EVALUATION

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Abstract

First tier deterministic chronic avian risk assessments for organophosphate nematicides often indicate a high theoretical long-term risk to birds due to the generally high intrinsic toxicity of these compounds in conjunction with high application rates. For a more realistic refined chronic risk assessment, considering the theoretically most endangered avian feeding guild, i.e. earthworm-eating birds, more detailed information will be needed on the realistic exposure situation. Therefore, representative exposure data have been generated under practical use conditions. a probabilistic risk assessment approach has been developed to account for the specific chronic exposure pattern on the one hand, the dose-related onset/continuation of chronic effects as well as the avian metabolism of the active substance on the other hand. This approach can reveal the probability for different focal species to exceed a specific margin of safety and assess the likely consequences for the reproductive performance of the populations involved.

Introduction

Tier 1 risk assessments aim at a rapid, approximate evaluation of the risk of plant protection products. Therefore, several worst case assumptions and simplification are combined to render the decision process easier. For nematicides, Tier 1 risk assessments often indicate a high theoretical risk due to their relatively high toxicities and application rates. While first tier risk assessments generally consider toxicity and application rate, other factors, which are especially relevant when assessing the risk of granular formulations, are ignored. For example, high exposure levels in relevant matrices (e.g. earthworms, granules, plants) are observed only during a short time window. In addition, residue levels in earthworms usually show an extremely high variability. Thus, we developed a refined risk analysis scheme for earthworm eating birds which includes all relevant factors and variabilities to evaluate the chronic risk posed by granular organo-phosphate nematicides. This analysis scheme is based on field measured exposure data (time-dependent residue levels in earthworms, portion of time (PT) of relevant bird species) in combination with probabilistic Monte Carlo simulations, which have been used for several decades in many scientific disciplines, but were only recently introduced into ecotoxicology.

Methods

A probabilistic model was developed which is based on the standard formula for chronic risk assessments:

$$ETE_{lt} = \frac{FIR}{BW} \cdot C_0 \cdot MAF \cdot f_{twa} \qquad \text{(Equation 1)}$$

For parameterisation of the model, field trials were conducted to determine the exposure level under practical use conditions. These trials made it possible to determine the extent of worm contamination and at the same time the weight of single worms, respectively. The availability of individual worm weights enabled food intake to be calculated by simulating the ingestion of earthworms until the daily energy requirements of a bird was met (based on earthworm wet weight, moisture and energy content). Thus, equation 1 was modified as follows (assuming one application per season):

$$ETE_{lt} = \frac{\sum_{d=0}^{N} \left(\frac{\sum_{i=1}^{n} R_i}{BW} \cdot PT \cdot PD \right)}{N} \qquad \text{(Equation 2)}$$

where n is the number of earthworms eaten by a bird on day d, R_i is the amount of residues in the n^{th} earthworm and N is the number of days considered for calculation of the time weighted average.

The exposure was calculated based on earthworm-intake, the level of earthworm contamination (field data), the portion of time a bird species of concern spends in the respective crop (PT, field data) and assuming that birds feed exclusively on earthworms (PD=1). Dose-response curves from chronic laboratory studies made it possible to estimate the magnitude of the effect and the toxicity exposure ratios.

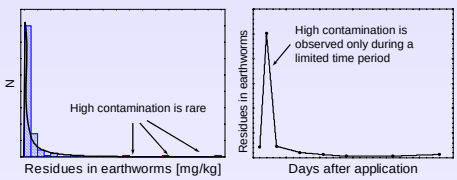

Figure 1. The amount of residues in earthworms directly after application of a granular organophosphate nematicide and the decrease of residues over time. Data were obtained from field trials.

Results

Monte Carlo simulations revealed the percentage of cases in which the actual exposure (by ingestion of contaminated earthworms) reached or exceeded the NOEAEC ("No Observed Ecological Adverse Effect Concentration", see figure 2). In a specific example, the NOEAEC was approached only in 1.0% of all cases. Based on dose-response relationships, it was also possible to estimate the magnitude of the expected effect could be estimated in animals for which the calculated ETE was above the NOEAEC. In our example, it could be shown that the effect expected in 1.0% of all birds of a species of concern is a reduction in reproductive performance by not more than 10%. For comparison, the only relevant information from a purely deterministic long-term avian risk assessment is that the Annex VI-trigger value of Dir. 91/414 is either breached or met (TER_{LT} < 5 or TER_{LT} > 5).

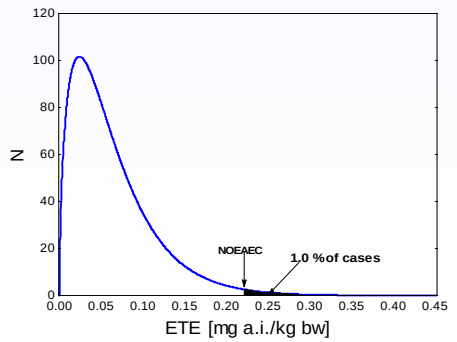

Figure 2. The probability distribution of the exposure to birds after application of a granular organophosphate nematicide via ingestion of earthworms. The filled area marks the probability of those cases where the exposure exceeds the NOEAEC.

Although TER_{LT} calculations are redundant for probabilistic risk assessments, because the risk can be evaluated directly (i.e. by the percentage of cases in which an effect is observed and/or by the extent of the expected effect), they were also calculated here in order to facilitate comparisons with the Tier 1 approach. Probabilistic analyses make it possible to determine not only a single TER_{LT}-value, but also the probability at which a given TER_{LT} is expected. Figure 3 shows an example of a TER probability plot. In this example, the 10^{th}-%tile of all chronic TERs amount to 1.96 (i.e. ≈2). This means that in 90% of all cases the exposure is only half of the NOEAEC or less. The exposure reaches or exceeds the NOEAEC only in 1.0% of all cases, i.e. the TER is equal or lower than 1 only in 1.0% of all cases (i.e. the 99^{th}-%tile).

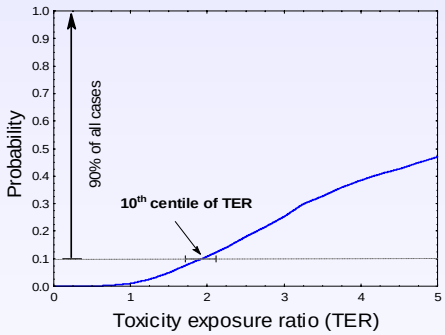

Figure 3. A probability plot of the chronic Toxicity Exposure Ratio (TER_{LT}). The graph shows at which probability a given TER_{LT} is expected. In this example, the TER_{LT} is above 1.96 (lower CI: 1.82, upper CI: 2.09) in 90% of all cases (= 10^{th}-%tile).

Conclusions

- Detailed information from representative field trials allow to estimate the exposure of earthworm eating birds, posed by granular organophosphate-nematicides, in a meaningful way.
- The comprehensive set of generated data (level of contamination of individual worms, time-course of residue levels, individual earthworm weights, PT-values of bird species of concern, dose-response data from avian reproduction studies) enables a probabilistic Monte Carlo approach to be applied in an ecotoxicologically sound way as a basis for a conclusive risk assessment and risk management.
- The probabilistic model estimates and scrutinizes the risk in much greater detail compared to first tier analyses. Specifically, the probabilistic approach reveals the percentage of birds in which an effect is expected as well as the magnitude of this effect.
- Additionally, traditional TER_{LT} values can be calculated for comparison with Tier 1 results.