Assessing the Risks of Persistent Organic Pollutants to Top Predators

Despite the claims that accurate risk assessment of persistent organic pollutants (POPs) and persistent, bioaccumulative and toxic (PBT) substances can be unfeasible, there is ample evidence in scientific literature that safe levels for POPs and PBTs can be defined and that risk assessment, including potential for secondary poisoning, is possible with multi-disciplinary input from wildlife ecology, ecotoxicology and analytical chemistry. This FOCS will discuss two main methods of risk assessment of secondary poisoning of top predators by POPs/PBTs and illustrate them with concrete examples. In the tissue-based approach, the most direct method of assessing risk to top predators, concentrations of a POP/PBT in a tissue sample are compared to concentrations of the substance that are known to cause adverse effects to the species. The alternative, diet-based approach compares the average daily intake of a POP/PBT substance via the diet to a threshold concentration level above which the predator is known to experience adverse effects.

Risk assessment is a systematic process used to evaluate the risks posed by a chemical based on a comparison of an organism’s exposure level to the threshold levels above which that chemical causes adverse effects to the organism. For many chemicals, this procedure is well-established in European legislation, but for some so-called substances of very high concern (SVHCs) this raises challenges. For PBTs, a specific group of SVHCs which are persistent, bioaccumulative and toxic, it is often claimed unfeasible to derive safe exposure levels with sufficient reliability. This is also assumed to be the case for persistent organic pollutants (POPs). POPs are PBT substances which also have the potential for long-range transport in the environment and are regulated under an international treaty, the Stockholm Convention. A significant challenge to risk assessment of POP/PBTs is their potential to bioaccumulate through food-chains, which can result in secondary poisoning of top predators if adverse effect levels are attained. Nevertheless, in order to identify safe and suitable alternatives to SVHCs, REACH Article 60(5a) requires an assessment of the risks of alternative substances in order to ensure that use of an substituted chemical would result in a true reduction in risk to human health and the environment. Under the Stockholm Convention, a risk profile is required during the review of a POP substance.

A key element of risk posed by POP/PBT substances is secondary poisoning of organisms from the higher levels of a food chain. This phenomenon occurs when a predator, through the consumption of contaminated prey, achieves a critical body residue concentration of a substance that leads to toxic effects. Due to this indirect exposure through trophic level, the risk assessment of POPs/PBTs is more complicated for top predators than for species at the lower end of the food chain. Traditionally, environmental risk assessment is carried out by comparing toxicity threshold values above which adverse effects are observed (predicted no-effect concentration or PNECs) with environmental concentrations of a contaminant measured or predicted from an exposure assessment (predicted environmental concentration or PECs). However, risk assessment of secondary poisoning of top predators by POPs/PBTs is complicated by the following...
Exposure assessment of top predators to POPs/PBTs is traditionally based on extrapolation from concentrations in abiotic compartments or in low trophic-level organisms which means that several transformation steps are required in order to estimate effect concentrations at higher trophic levels of the food chain. Uncertainty in the data increases with each transformation step.

Since it is generally more elaborate, more costly and not legally permissible to carry out ecotoxicity tests with top predator species, there is a lack of existing measured internal effect concentrations. As a result, calculation of potential toxicity thresholds to top predator species must frequently rely on results from laboratory ecotoxicity tests on other mammalian species which also introduces uncertainty to the risk assessment.

Despite these complications, risk assessment, including potential for secondary poisoning, is possible with multi-disciplinary input from wildlife ecology, ecotoxicology and analytical chemistry. Two main approaches that lead to more direct and more accurate, site specific risk assessment of POP/PBTs to top predators are reviewed below:

**Tissue-based approach**

The most direct method of assessing risk to top predators is the tissue-based approach. In this approach, an exposure assessment is performed by chemically analysing a top predator tissue sample (e.g. blubber, hair, or blood) to determine the internal tissue residue level. The POP/PBT concentration in a top predator body tissue is then compared to concentrations which are associated with adverse health effects for that top predator. Exposure-effect relationships can be determined from laboratory, semi-field, or field studies and are usually expressed as toxicity or threshold reference values (TRVs).

The tissue-based approach has been successfully used to estimate the risks of POPs/PBTs to birds (e.g. kingfishers and cormorants), and terrestrial and marine mammals (e.g. mink, seals and dol-

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**Surrogate species**

**Measured internal tissue level in top predator**

**internal adverse health effect concentrations of top predator**

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**Surrogate species**

**Toxicity data on dose basis of surrogate species**

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**Diet-based approach**

**Receptor species**

**Measured internal tissue levels in diet of top predator**

**Diet composition of top predator**

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**Receptor species**

**Toxicity data on dose basis using top predator as target species**

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**Surrogate species**

**internal adverse health effect concentrations of surrogate species**

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**Tissue-based approach**

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**Diet-based approach**
One of the best-documented examples is a risk assessment of PCBs for mink from North America. PCB tissue residue levels are available from a large number of monitoring studies, and extensive laboratory experiments have shown the adverse effects and the mechanism of action of PCBs for mink at different tissue residue levels. Comparing results from these monitoring studies with threshold values from the exposure-effects studies have demonstrated that PCBs are still a risk for some mink populations in North America, and that uncertainties in risk estimation can be reduced by using the tissue-based approach.

In practice, the availability of internal exposure-effects relationships for POPs/PBTs in top predators is limited, so these may have to be extrapolated from surrogate species, such as rats and mice. Various additional factors need to be considered in this extrapolation to account for differences between the surrogate species and the top predator, including differences in metabolism, assimilation efficiency, toxicokinetics, and body size, as well as other physiological, behavioural and ecological parameters. Mink is frequently used as a surrogate species for other mammalian top predators. This mammal is sensitive to organochlorines and metals, and has been used in the risk assessment of PCBs for dolphins and other marine mammals.

An alternative approach is to compare measured tissue levels with biomarker (a measurable indicator of adverse physiological effects) responses in the top predator. The disadvantage of this is that there is greater uncertainty about the cause-effect relationships of specific chemicals because animals from the field are exposed to a mixture of compounds (both natural and man-made). In addition to this, it is not always easy to interpret whether a biomarker response indicates a truly adverse effect. Despite this, several interesting studies on polar bears show relationships between internal POP/PBT levels, biomarkers such as vitamin A and thyroid hormone levels, and the overall health status of the bears.

**Diet-based approach**

The diet-based approach to assessing the risks of POPs/PBTs to top predators also compares the environmental exposure of an organism to a toxicity or threshold value. However, when using this method, the exposure is estimated based on the total dietary intake of the POP. Information on predator diets is combined with information on POP/PBT levels in the main prey items to estimate the average daily intake of POPs/PBTs.

Exposure assessment based on diet requires a realistic site-specific estimate of the predator’s diet composition, samples of the predator’s diet (e.g. fish), measured concentrations of POP/PBTs in these prey items, and predator ingestion rates. Two methods are available for estimating realistic dietary exposure to a POP, based on the site-specific diet composition of a top predator:

- summation of the POP concentrations measured in individual food items
- the food-basket approach

The advantage of the first approach is that detailed information on the intake of POP/PBTs from individual prey species is obtained. Predator diet composition can be quantified using analysis of stomach contents and excrement, or by using fatty acid fingerprinting methods. Studies have shown that the main prey species are not always the main sources of POP/PBT intake for a top predator. For instance, one Dutch study found that the main prey of otters was cyprinid fish (45%), with eels comprising only 9% of the diet. However, PCB intake by otters was mainly from eels (45%), with a lower intake from cyprinids (30%), because the PCB concentration in eels was much higher.

In the second approach, an estimate of the intake of a contaminant from the diet is obtained from analysis of a food basket instead of individual food items. Representative prey items for the predator population are selected based on site-specific diet analysis and food-basket homogenates are pre-
pared by combining individual prey items. The advantage of the food-basket approach is that fewer POP/PBT measurements have to be performed as only an overall value for the food basket is required. The food-basket approach is often used to estimate exposure in human health risk assessments.

Once determined, the exposure of the top predator, expressed as an average daily intake (mg/kg bw/day) can be compared to a critical adverse-effect threshold obtained from a dose-response study. If no information on a dose-effect relationship is available for the specific top predator, extrapolation from a surrogate species can be used. A large dataset of POP/PBT dose-effect relationships is available for rats, mice and quail.

Advantages of the tissue- and diet-based approaches

Using the tissue- and diet-based approaches described above, accurate risk assessment of secondary poisoning by POPs/PBTs in top predators is feasible with multi-disciplinary input from wildlife ecology, ecotoxicology and analytical chemistry. The advantage of these methods is that they reduce uncertainties in the estimation of the exposure of top predators to POP/PBTs and resulting possible adverse effects.

In practice, however, the availability of dose-response data and internal exposure-effects relationships for POPs/PBTs in top predators is limited, so this information may have to be extrapolated from surrogate species. Furthermore, mammal and bird toxicity studies usually report effects based on doses and rarely provide information on internal tissue residue levels.

Uncertainty in assessing the effects of POPs/PBTs on top predators would be substantially reduced if toxicity studies included the determination of tissue residue levels in test species. This would provide a powerful link between environmental exposure assessments, tissue residue levels, and adverse effects, and would help to ensure that top predators worldwide are appropriately protected from any harmful effects caused by exposure to POPs/PBTs.

References:
