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# IMPLEMENTING ATMOSPHERIC FATE IN REGULATORY RISK ASSESSMENT OF PESTICIDES: (HOW) CAN IT BE DONE?

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**Abstract.** Atmospheric fate of pesticides and their possible effects in ecosystems beyond the immediate surrounding of the application site are not actively considered in currently used regulatory risk assessment schemes. Concern with respect to atmospheric transport and subsequent deposition of pesticides in non-target areas is however growing. In this article the results of discussions on the possibilities of implementing atmospheric fate in regulatory risk assessment are presented. It is concluded that implementing atmospheric fate in regulatory risk assessment schemes is possible and that, from a scientific point of view, these schemes should distinguish between pesticides on the basis of both their possibility/probability to reach non-target areas and on their toxicity. This implies that application of the precautionary principle or use of intrinsic pesticide properties alone is not considered justifiable. It is recommended that the risk assessment scheme should follow a tiered approach. The first tier should be entered only if the existing regulatory risk assessment procedure, including a local PEC:PNEC calculation, has been passed and involves a test for the pesticide's total atmospheric emission potential, *i.e.* its potential for becoming airborne during and after application. The second tier, which is only entered if the total emission potential is higher than a certain trigger value, should consist of a PEC:PNEC calculation for regional off-site areas (10-50 km) (tier 2A). If the pesticide's atmospheric transport potential is expected to exceed a certain value, the PEC:PNEC ratio should also be calculated for more remote areas (>1000 km) (tier 2B).

**Keywords:** atmospheric fate, pesticides, risk assessment, tiered approach

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## 1. Introduction

To date, the atmospheric fate of pesticides and their possible effects in regional off-site or more remote areas are not actively considered in existing regulatory risk assessment schemes. Exceptions are the assessment of the impact of spray-drift on adjacent non-target areas and the assessment of the effects of local air-quality on workers and nearby living humans. Concern is however growing with respect to atmospheric transport and subsequent deposition of pesticides in non-target areas beyond the immediate surroundings of the application site. This concern has already lead to the inclusion of the pesticides aldrin, chlordane, chlordecone, DDT, dieldrin, endrin, heptachlor, HCB, HCH, mirex and toxaphene in the draft POP-protocol (UN-ECE, 1998) that was drawn up under the auspices of the United Nations Economic Commission for Europe's (UN-ECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and that was accepted on June 24$^{th}$, 1998 at the Ministers Conference in Aarhus, Denmark. In April 1998, the Health Council of The Netherlands organised a workshop on 'Fate of pesticides in the atmosphere; implications for risk assessment' in Driebergen, The Netherlands. During this workshop a working group was formed to discuss the possibilities of implementing atmospheric fate in regulatory risk assessment. The members concentrated on environmental risk assessment. This article summarises the discussions and conclusions.

## 2. Current regulatory activities on pesticides

### 2.1. UN-ECE POP-PROTOCOL

The objective of the UN-ECE POP-protocol is 'to control, reduce or eliminate discharges, emissions and losses of persistent organic pollutants'. Persistent organic pollutants are defined as 'set of organic compounds that: (i) possess toxic characteristics, (ii) are persistent, (iii) are liable to bioaccumulate, (iv) are prone to long-range atmospheric transport and deposition and (v) can result in adverse environmental and human health effects at locations near and far from their sources (UN-ECE, 1998). Most of the pesticides in the protocol are listed under Annex I of the protocol, which contains the substances that are scheduled for elimination. The POP-protocol, however, aims at reducing *existing* risks because several of the organochlorine pesticides in the protocol, such as DDT and HCH, have already found their way to remote areas such as the Arctic and have imposed risks on ecosystems (Barrie *et al.*, 1992; Bidleman, this issue). Furthermore it can be expected that adding additional pesticides to the internationally agreed POP-list is due to take ample time and to encounter many difficulties. For these reasons it seems better to include the atmospheric fate of pesticides in the regulatory risk assessment at the moment when a manufacturer asks permission for a pesticide to be admitted to the market and to minimise the risk of atmospheric dispersion to non-target areas beforehand.

### 2.2. EU DIRECTIVE 91/414/EEC

The concern about the atmospheric fate and behaviour of pesticides is also reflected in the EU Authorisations Directive 91/414/EEC (EC, 1991) under the terms of which admittance of pesticides is considered in the European Union. In Annex III of this Directive, prediction of 'the level of residues in air, to which man, animals and non-target organisms may be exposed (acute and chronic)' is asked for (EC, 1995). In this Annex III, the EPPO/CoE decision making scheme (EPPO/CoE, 1993) is referred to, in which a sub-scheme for air is being implemented. In this sub-scheme the various temporal and spatial scales of atmospheric pesticide dispersion are distinguished. Actual guidelines for implementing atmospheric fate and behaviour in risk assessment procedures or guidelines for regional off-site or more remote risk assessment could however not yet be presented in the form of an easily usable regulatory risk assessment tool. This is largely because the underlying science concerned is still under development.

## 3. Possibilities for implementing atmospheric fate of pesticides in regulatory practice

### 3.1. APPLYING THE PRECAUTIONARY PRINCIPLE

When discussing the possibilities of reducing or minimising risks of pesticides in non-target areas, 'the precautionary principle' was brought up by several participants. The interpretation of this principle seemed however to vary considerably. The most strict interpretation that was pronounced, implied that pesticides should not be present in non-target areas at all because they 'do not belong there', which is more or less an ethical point of view. In practice this would mean that either the pesticide may not be used at all or the pesticide may be used but may not leave the application areas in such quantities that it exceeds the level of detection in non-target areas. This interpretation of the precautionary principle does not account for differences in exposure or for differences in toxicity of different pesticides.

Another interpretation of the precautionary principle was one that says that levels in non-target areas should not become higher than the present ones (the stand-still principle). The stand-still principle would only be applicable to pesticides that are already in use or have been used in the past. For a new pesticide the stand-still principle therefore coincides with the aforementioned more strict interpretation of the precautionary principle. The stand-still principle does not account for differences in exposure or differences in toxicity of pesticides either.

Use of safety factors was also mentioned as a kind of precautionary principle. By applying safety factors to the results of the exposure and/or effect assessment, one can incorporate additional safety into the risk assessment procedure to prevent 'false positives' (pesticides that are unjustifiably considered safe to use).

As the members of the working group were of the opinion that regulatory risk assessment schemes should distinguish between pesticides on the basis of both their possibility/probability to reach non-target areas and their toxicity, they concluded that it would not be appropriate to incorporate atmospheric fate in regulatory risk assessment schemes on the basis of the most strict interpretation of the precautionary principle or on the basis of the stand-still principle. Use of safety factors was, however, considered justifiable and necessary in order to account for uncertainties in toxicity and environmental behaviour.

### 3.2. USING INTRINSIC PESTICIDE PROPERTIES

One way to distinguish pesticides that may reach non-target areas from those that will not, would be to use certain intrinsic (physico-chemical) properties as regulatory criteria. Examples of intrinsic pesticide properties that are already being used in regulatory risk assessment schemes are the half-life with respect to (bio)degradation $DT_{50}$, the octanol-water partitioning coefficient $K_{ow}$ as a measure for bioaccumulation potential and the adsorption coefficient $K_{om}$ for sorption to organic matter. In some risk assessment schemes intrinsic properties are used as cut-off values, in others they are used to calculate for example the risk that a pesticide leaches to the groundwater (CTB, 1999; Winkler *et al.*, 1999). In the case of implementing the atmospheric fate of a pesticide in a risk assessment scheme, one must find the intrinsic properties that govern the emission of the pesticide to the atmosphere during and after application and the properties that determine its atmospheric transport potential. For the properties that govern the emission to the atmosphere, cut-off values could be set. For the properties determining the atmospheric transport potential this is more difficult. The problem here is that, if one wants to protect not only remote areas at more than 1000 km distance but also regional off-site areas at 10-50 km distance, the cut-off values based on the 10-50 km distance will probably be so restrictive that hardly any pesticide will comply with the criterion. A property determining this transport potential could, however, be used for calculating the average or maximum distance of transport and the percentage of the emitted pesticide arriving at a certain distance. Intrinsic pesticide properties (co)determining the emission to the atmosphere are the saturated vapour pressure P, Henry's law constant H and the octanol-air partitioning coefficient $K_{oa}$. The atmospheric transport potential is determined by a pesticide's atmospheric half-life which is governed by its (photo)chemical degradation rate $k_{atm}$ and its dry and wet deposition removal rate (Atkinson *et al.*, this issue; Van Pul *et al.*, this issue). However, intrinsic properties that determine a pesticide's potential for atmospheric emission and/or transport do not say much about the magnitude of the exposure concentration (as the volume used is important as well) and nothing at all about its toxicity.

The working group held the opinion that regulatory risk assessment schemes should distinguish between pesticides both on the basis of their possibility/probability to reach non-target areas and on their toxicity. It was therefore concluded that intrinsic pesticide properties determining the atmospheric fate of pesticides alone should not be used to determine whether or not a pesticide can be admitted to the market.

### 3.3. COMPARING ENVIRONMENTAL CONCENTRATIONS WITH (NO) EFFECT CONCENTRATIONS

A common way to assess the environmental risks of a pollutant is by comparing the measured or Predicted Environmental Concentration (PEC) with an effect level for a particular organism or for the ecosystem as a whole. Often the Predicted No Effect Concentration (PNEC) is chosen as the critical limit (the limit above which unacceptable effects take place). The PEC:PNEC ratio then gives an indication of the risk of harmful effects as a result of the exposure to the pollutant. For pesticides, this PEC:PNEC approach is used in several existing regulatory schemes to assess the risks at or near the site of application (EC, 1991; EC, 1995; EC, 1997; EPPO/CoE, 1993; Greig-Smith, 1992; UK PSD, undated). For risk assessment of substances other than pesticides, the PEC:PNEC approach is also often used (EC, 1996; EC, 1998; RIVM, 1998). For this reason and the fact that the PEC:PNEC approach incorporates both exposure and toxicity, it was concluded that the risk assessment of a pesticide in regional off-site and more remote areas should also be based on a PEC:PNEC approach or a procedure equivalent to it. The question, however, that directly follows this conclusion is how to determine the PEC and PNEC for regional off-site and more remote areas?

With respect to the PNEC one could answer that the risk assessment should be directed at protecting the entire regional off-site or remote ecosystem and that this aim could be attained by basing the PNEC on the sensitivity of one or more key indicator species in the ecosystem of concern or on a species sensitivity distribution. This approach would comply with existing risk assessment schemes. It can however be questioned whether it is to be expected that the sensitivity (expressed in the value of the PNEC) of species in regional off-site or remote ecosystems is much different from that of species at the site of application. If the sensitivities are more or less comparable, one might expect that the PEC:PNEC ratio in the off-site or remote area will always be smaller than the ratio at the site of application because it is to be expected that the PEC in off-site and remote areas is lower than at the site of application itself. However, as long as it is conceivable that certain key species or ecosystem functions are more sensitive under other (*i.e.* harsher) environmental conditions, it is advisable to determine a PNEC specifically for the regional off-site and remote ecosystems. Another consideration that supports this advise is the fact that biomagnification may play different roles in different ecosystems. This does not automatically imply that the manufacturer of the pesticide should be required to test the toxicity on all kinds of 'exotic' species. The most simple way to arrive at a PNEC for off-site and remote ecosystems is by applying a safety factor to the PNEC that is used in the local risk assessment. Another method would be to use models, including food chain or food web models representing the situation in the remote ecosystem, to determine 'a remote PNEC'.

Determining the PEC in regional off-site and remote areas was thought to be more difficult than estimating the 'remote PNEC'. The different spatial scales* for regional off-site (10-50 km) and remote (> 1000 km) areas and the fact that information is needed on the volume of use and the spatial pattern of use in the region (for off-site PEC) or even the world (for remote PEC) make it difficult to estimate the PEC. This information on volume and pattern of use is hard to obtain for existing pesticides and does not yet exist for new ones. A possible approach for the regional off-site area would be to assume that all of a pesticide that is emitted into the atmosphere from one hectare of agricultural area will be deposited on one hectare of non-target area such as a nature reserve. This is called the 'unit surface area approach' (Van de Meent *et al.*, 1995). A refinement would be to correct the input to the non-target area with a factor based on the ratio between total treated agricultural area and total non-treated area in the region. Another refinement would be to introduce a time-dependency, which could take into account the fact that in some cases 90% of the emission takes place during the first 24 hours and that in other cases it may take a year before 90% of the emission has occurred. The 'unit surface area approach', and to a lesser extent the refined methods, would be worst case approaches. Another approach to calculate the regional off-site PEC would be the 'scenario approach'. In this approach a hypothetical standard region consisting of both agricultural fields and non-agricultural areas is drawn up. In the agricultural fields, the pesticide of concern is assumed to be used with typical spatial and temporal variations. For this region atmospheric emissions, transport and deposition and the PEC in the non-target areas are estimated by model calculations. Both the 'unit surface area approach' and the 'scenario approach' can be applied for existing and new pesticides.

For remote areas, the calculation of a PEC becomes more uncertain but is still possible. The 'unit surface area approach' could be applied if the losses

* The spatial scales presented here are just examples to make a clear distinction between off-site, but still relatively nearby areas and really remote areas. This does however not mean that the area between 50 and 1000 km should not be considered.

due to atmospheric degradation and atmospheric deposition along the trajectory to the remote area are accounted for. The 'scenario approach' is less appropriate for calculating PECs in remote areas as the input data can only be estimated very roughly and the results would bear a large uncertainty.

### 3.4. TIERED APPROACH

As not every pesticide has a high potential for becoming airborne and therefore not every pesticide poses a risk for off-site or remote areas, it was concluded that regulatory PEC:PNEC risk assessment for these areas should be restricted to only those pesticides that are expected to have a certain minimum atmospheric emission potential. Such a distinction on the basis of atmospheric emission potential assessment leads to a tiered approach in which several levels of assessment are distinguished. In this tiered approach, the first tier is entered only if the existing regulatory risk assessment, including a local PEC:PNEC calculation, has been passed. The first tier involves the comparison of the atmospheric emission potential, based on intrinsic pesticide properties, with a trigger value. If the intrinsic properties indicate that the estimated total atmospheric emission potential, *i.e.* the potential for becoming airborne during and after application, is lower than the maximum that is considered acceptable, authorisation of the pesticide is possible and the second tier is not entered. In the case that the intrinsic pesticide properties indicate a total emission potential that is higher than considered acceptable, a second tier of risk assessment has to be entered. This second tier involves a PEC:PNEC based risk assessment for both off-site (tier 2A) and remote areas (tier 2B). The distinction between off-site (10-50 km) and remote (>1000 km) can be based on a trigger value for an intrinsic pesticide property determining its atmospheric transport potential such as its atmospheric half-life $DT_{50,atm}$. A method for determining the atmospheric transport potential, based on intrinsic compound properties, is given by Van Pul *et al.* (1998) and could be used in the second tier. Within the second tier, first the off-site (10-50 km) risk assessment (tier 2A) is performed. If this off-site risk assessment results in a PEC:PNEC ratio that is higher than acceptable, authorisation is not possible. If the PEC:PNEC ratio is acceptable, the pesticide is subsequently checked for its transport potential. If the transport potential is not higher than the trigger value, a remote risk assessment is not necessary and the authorisation of the pesticide is possible. Only if the transport potential is higher than the trigger value, the remote risk assessment (tier 2B) has to be performed. Here again the PEC:PNEC ratio determines whether authorisation of the pesticide is possible. The tiered approach discussed here, is depicted schematically in figure 1. Another tiered approach based on volatility and behaviour in air is currently under development in Germany. This approach is based on the experience of authorisation according to guidelines of the German Biologische Bundesanstalt für Land- und Forstwirtschaft (BBA, 1990).

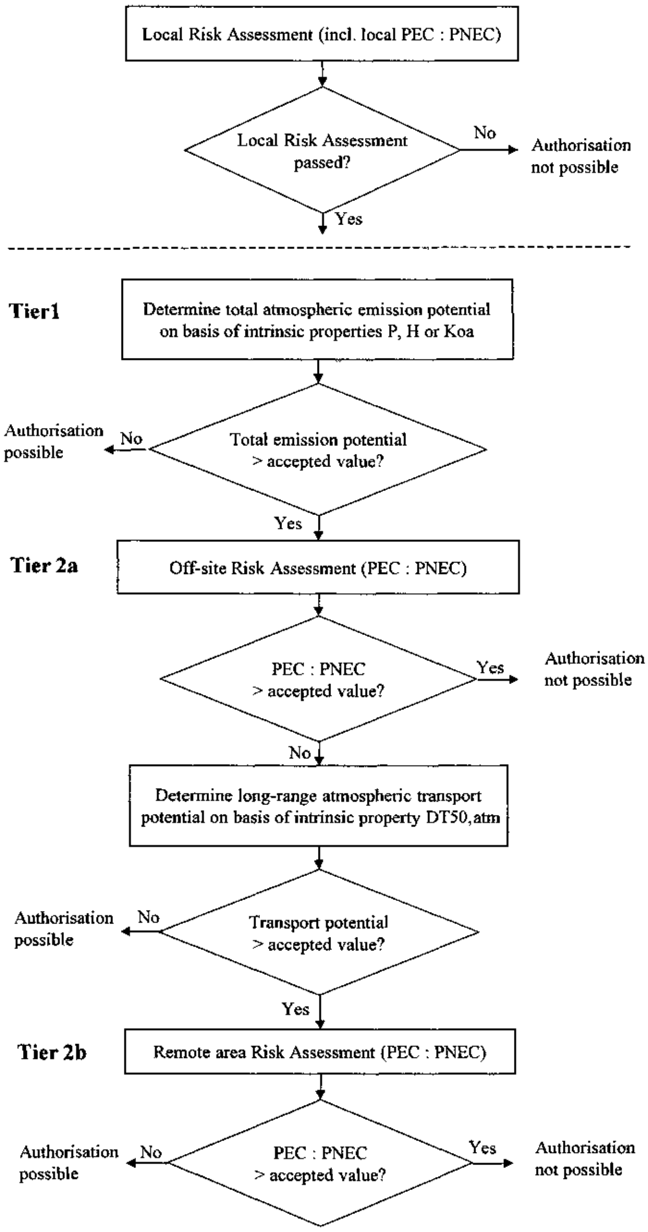


*Figure 1.* Tiered approach for implementing atmospheric fate in regulatory risk assessment of pesticides. The tiered scheme is entered only if the local risk assessment has been passed. (The abbreviations are explained in the main text.)

## 4. Conclusions and recommendations

The main conclusion of the members of the working group is that it is feasible to implement atmospheric fate in regulatory risk assessment of pesticides. They further conclude that this would, from a scientific point of view, not be acceptable on the basis of the precautionary principle or solely on the basis of intrinsic pesticide properties. They recommend to follow a tiered approach. The first tier, which is entered only if the existing regulatory risk assessment procedure, including a local PEC:PNEC calculation, has been passed, should involve a test for the pesticide's total atmospheric emission potential. This potential should be estimated with the help of intrinsic pesticide properties such as the saturated vapour pressure, Henry's law constant and the octanol/air partitioning coefficient. Trigger values for the total emission potential could be established to be able to determine whether the second risk assessment tier should be entered. This second tier should consist of a PEC:PNEC calculation for regional off-site areas (10-50 km) (tier 2A) and, if the pesticide's atmospheric transport potential is expected to exceed a certain value, also for more remote areas (>1000 km) (tier 2B). This atmospheric transport potential can be estimated on the basis of intrinsic pesticide properties including the (photo)chemical degradation rate and properties that govern the deposition velocity. We recommend to investigate which (combination of) intrinsic pesticide properties predict the atmospheric emission and transport potentials best and to work out further the PEC:PNEC based risk assessment procedures for regional off-site and remote areas.

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