SWISS FINAL REPORT ON THE
VALIDATION OF OECD PESTICIDE
AQUATIC RISK INDICATORS

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Executive Summary

Within the scope of the OECD pesticide risk reduction program a project for the development of pesticide aquatic risk indicators was initiated in 1998. As a result, three indicators (REXTOX, ADSCOR and SYSCOR) were developed to estimate relative risk of agricultural pesticide use to surface water organisms. They were designed as political tools, for national authorities to follow progress of risk reduction measures or plan pesticide management.

The indicators combine pesticide properties, pesticide use data such as applied dose rate, application characteristics such as method of application, and some environmental parameters. In contrast to various existing approaches which calculate hazard indices based on worst case assumptions, the OECD aquatic risk indicators calculate risk indices based on actual use data. In all three indicators relative risk values are estimated by calculating the «exposure:toxicity» ratio. While all indicators include toxicity to the same organisms (algae, daphnia, and fish), they differ in the approach of exposure estimation (Chapter 2). REXTOX uses a mechanistic approach and is the only indicator considering several field site properties. ADSCOR and SYSCOR are scoring indicators, assigning scores to variables assumed to contribute to aquatic risk.

In 2000, the OECD aquatic risk indicator pilot project started as follow up to the indicator development project. Its scope was to allow several countries to test the indicators with their own input data, to assess the indicators’ usefulness, validity, and acceptability as policy tools. Apart from Switzerland, Denmark, France, Germany, Japan, Norway, and USA participated in this project.

Input data

Compilation of reliable input data for the indicators (Chapter 3) turned out to be time consuming. In general, properties of active ingredients were derived from handbooks, registration dossiers, or the open literature. For most pesticides physico-chemical data such as log Kow and solubility were readily available. In contrast, for degradation rates in natural water and long term toxicity values significant data gaps were met. In some cases, values which varied over several orders of magnitude were encountered, which made selection of one single value difficult. Swiss use data were only available for the years 1997 and 1998 for the catchment areas of three lakes, namely Greifensee, Baldeggersee, and Murtensee. The limited availability of use data did not allow the calculation of time trends or extrapolation to a national level.

Validation

The Swiss contribution to the indicator validation, as presented in Chapter 4, included three parts: Sensitivity analysis, exemplary and scenario calculations, and comparison of indicator
results with monitoring data. Only two of the three indicators could be thoroughly tested, because the third (SYSCOR) was still under development during the final phase of the project. For the two other indicators it was shown, that apart from toxicity the indicators primarily are driven by the scaling variables «applied amount of pesticides» (REXTOX) or «area treated» (ADSCOR).

It became obvious that revision and adaptation to the specific Swiss situation would be necessary for both, ADSCOR and REXTOX. Thereby, most important in REXTOX is the need for recalibration of the relative weight of the two considered input pathways of pesticides to surface waters «spray drift» and «runoff», as the former is clearly overestimated. In ADSCOR, the combination of different scales for variables such as scores and real values has to be reconsidered carefully.

It was found that REXTOX may be useful as add-on tool for priority setting of monitoring programs as the indicator reflects the relative portion of pesticides found in surface water, in general, quite well.

**Use of indicators**

Indicator results can be presented in different ways (Chapter 5), in order to identify causes for relative risk changes, regional differences or «risky» crops or pesticides, depending on the questions to be addressed.

Apart from above mentioned need for revision, REXTOX and ADSCOR are seen as useful tools to interpret actual pesticide use data in combination with pesticide properties with respect to relative risks to aquatic organisms. Nevertheless, it should be emphasised, that indicator results may never be used as such, but need to be analysed carefully and the interpretation has to be committed to experts. Thereby the limitations of indicators concerning their meaningfulness and completeness (Chapter 6) have to be well considered and communicated. Indicators should never be used as single basis for decision making and the use of several indicators instead of only one seems to be appropriate.

At the time of writing this report it was not yet decided by the responsible Swiss authorities whether one or several of the three OECD indicators will be considered in the future. However, prior to further development or implementation of risk indicators in Switzerland, it is necessary that specific requirements, such as questions to be addressed, variables to be considered, intended users and target audience, and available resources are defined.
1 Introduction

1.1 OECD Pesticide Risk Reduction Program
Since 1994 the OECD is undertaking projects on behalf of pesticide risk reduction [4, 5]. Thereby, as a first step an investigation and survey of the situation of risk reduction activities carried out by several OECD and FAO countries in 1994-1995 was made [6]. It was found that several countries had made many efforts to reduce pesticide risks but seldom had adequate tools to measure their effects. As a result the idea to initiate a project on pesticide risk indicators was first mentioned at the 1995 OECD/FAO workshop on pesticide risk reduction in Sweden which was further refined at the 1997 OECD workshop on pesticide risk indicators in Copenhagen [7, 8]. There it was recommended to facilitate the development of pesticide aquatic risk indicators allowing OECD countries to measure progress in pesticide risk reduction. The Copenhagen workshop specified the following criteria:

- indicators should be designed specifically for use by national governments
- a series of indicators should be developed rather than just one «overall risk» indicator
- the purpose of the indicators should be to combine information on pesticide hazard and exposure with information on the quantity and conditions of pesticide use
- the indicators should be consistent with risk assessment but not duplicate it

The OECD pesticide aquatic risk indicator project started in 1998 and was carried out by a OECD Pesticide Risk Indicator Expert Group. It is important to note that this project is part of a larger OECD project to develop pesticide risk indicators for both, human health and the environment [9]. The aquatic risk indicator project focussed on the following goals:

- evaluation of existing indicators
- design of three new indicators which base on contrasting approaches
- testing, evaluation and refining of these developed indicators
- analysis of evaluation results

The risk indicator project results were presented at the 1999 OECD workshop on pesticide risk indicators in Braunschweig [3]. The workshop recommended to initiate a pilot project on the three OECD aquatic risk indicators.

1.2 OECD Pesticide Aquatic Risk Indicator Pilot Project
The pilot project started in February 2000. Its main purpose is to allow countries to run the three OECD aquatic risk indicators with their own pesticide use data and to assess the indicators' usefulness, validity and acceptability as policy tools [3].
The first phase (February to June 2000) served the pilot project participants to study the pesticide risk indicator project reports, identify own data and resources available for the project, and decide on their level of participation. The first meeting of pilot project participants was held in June 2000. Its main purpose was to report each countries grade of participation and create a network for sharing information.

The second phase of the project (July to December 2000) served to prepare input data on national or regional pesticide use as well as pesticide and environmental properties (see Chapter 3).

After a revision of the indicators by the Expert Group in 2000 the pilot project participants Denmark, France, Germany, Japan, Norway, Switzerland, and USA began to run the indicators in February 2001. At the second pilot project meeting in April 2001 experiences with indicator handling and first results were discussed.

In October 2001 the final meeting of the pilot project participants was held. After a two days session on each countries evaluation results a summary of findings on the three aquatic risk indicators was presented to the Pesticide Risk Reduction Steering Group. The following main decisions on how to conclude the project and proceed with future work on indicators were made:

- each project participant writes a technical report on the work carried out for the project as part of the final report on the aquatic pesticide risk indicator pilot project
- based on the report the OECD Risk Reduction Steering Group will present the pilot project results to the OECD Working Group on Pesticides in February 2002
- launch of a specific OECD web page focused on pesticide aquatic indicator work
- future work on terrestrial pesticide indicators will presumably be considered by the OECD

1.3 Goal of the Swiss contribution

The main goal was to gain experience in indicator handling with own pesticide use data. Additionally, the usefulness of both, OECD indicators and Swiss use data set was analysed.

In this report, the technical results of the validation of the OECD indicators by EAWAG and FAW (see Chapter 4) are presented. To facilitate the understanding of the indicators’ functioning a description is given in Chapter 2. Furthermore, additional information on particularities in connection with the collection of pesticide data is described in Chapter 3. Chapter 5 provides indicator results based on the Swiss pesticide use data set in connection with some aspects of indicator communication and presentation. Finally, conclusions and an outlook on the possible use of aquatic risk indicators is presented in Chapter 6.
2 OECD Pesticide Aquatic Risk Indicators

In the following a description of the principles of the three OECD indicators, called REXTOX, ADSCOR and SYSCOR is given in order to facilitate the conception of the validation in Chapter 4. Detailed information on the indicators can be retrieved on the OECD Pesticide Program webpage www1.oecd.org/ehs/pesticid.htm.

2.1 General aspects

All three OECD aquatic risk indicators are designed to calculate regional or national risk indices derived from specific pesticide use data. Thereby, all three indicators follow a general scheme in calculating risk (risk indices, respectively):

\[
\text{exposure value of active ingredient in surface water / toxicity value (LC}_{50}\text{ or NOEC)}
\]

Within the scope of the pilot project three target organisms were included, namely daphnia, fish, and algae. Other target organisms could be easily added with minor modification to the indicators [9, 10]. It should be noted, that the focus of the indicators is on exposure in surface water (and therefore on risks for surface water organisms). Leaching into groundwater is not considered.

Each indicator allows to calculate risks on several aggregation levels. For example, risks to individual aquatic organisms caused by individual pesticides reflect a low level of aggregation. These risk indices can be combined to calculate risks for any higher aggregation level such as risks to individual target organisms caused by individual crops, regions as well as the aggregation of risk indices to all target organisms across regions (i.e. national risk trend). It is important to note, that the higher the aggregation level of risk indices the more the causes for risk trends are masked.

Contrasts between the indicators are mainly due to their specific methodological approach of determining pesticide exposure values whereby the variables considered to contribute to pesticide exposure are mainly the same as shown in Table 2.1 below.
Table 2.1: Variables considered to contribute to pesticide exposure

Unlike SYSCOR, REXTOX and ADSCOR allow calculating of short-term (time scale minutes) and long-term (time scale weeks) exposure values. Most of the variables referring to pesticide use and fate as for example applied dose rate and DT$_{50,\text{soil}}$ respectively are used by all three indicators. In contrast, all environmental factors except water index (= proportion of the total agricultural area bordered by surface water bodies) are only used by REXTOX.

<table>
<thead>
<tr>
<th>Variable</th>
<th>REXTOX</th>
<th>ADSCOR</th>
<th>SYSCOR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pesticide use</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic area treated (BAT) [ha]</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cumulative area treated (CAT) [ha]</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Recommended dose rate (label rate) (RDR) [kg/ha]</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Applied dose rate (ADR) [kg/ha]</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Frequency of treatment per season</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Method of application*</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Width of spray drift buffer [m]</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Width of runoff buffer [m]</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Compliance with spray drift buffer [0-100%]</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Compliance with runoff buffer [0-100%]</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Environmental factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water index (WI)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Water depth [m]</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Slope of treated agricultural area</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Daily mean precipitation rate per region [mm]</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>% organic carbon of the soil</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Soil type [loamy or sandy]</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Crop stage treatment [early / late]</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Plant interception</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Pesticide fate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT$_{50,\text{water}}$ (half-life in water)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT$_{50,\text{soil}}$ (half-life in soil)</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>log K$_{ow}$**</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>K$_{ow}$ (derived from Kow)</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>K$<em>{d}$ (derived from K$</em>{ow}$ or K$_{oc}$ respectively)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Photolysis in water</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Solubility</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Notes see next page.
Notes to Table 2.1:
* Considered application methods within the indicator program:
  REXTOX: ground spray, air blast, aerial, granular broadcast, granular incorporated, pruning paint, soil sterilant, seed treatment
  ADSCOR: ground spray, air blast, aerial, granular broadcast, granular incorporated, pruning paint, soil sterilant, seed treatment, direct application to water (such for example in rice paddy fields)
  SYSCOR: ground spray, air blast, aerial, granular broadcast, granular incorporated, soil sterilant, direct application to water (e.g. in rice paddy fields)

** REXTOX: variable used to calculate log K_{oc}
  ADSCOR: variable used as scoring variable for bioaccumulation potential as well as to calculate log K_{oc} which serves as scoring variable for runoff potential
  SYSCOR: variable used to calculate K_d which functions as scoring variable

In the following the methodological concepts of the indicators as well as the produced results are described (for more detailed information please see [9, 10]).

2.2 REXTOX (Ratio of Exposure to Toxicity)
REXTOX is based on a Dutch risk indicator but includes also features of German and Danish indicators [3, 9]. In REXTOX a mechanistic approach is used to calculate an expected pesticide concentration likely to end up in surface water bodies. This approach is similar to exposure definition in regulatory risk assessment [9].

REXTOX considers only spray drift and runoff but not leaching and drainage as exposure routes. This approach was chosen as no agreed methods to calculate the latter two exist. As a result, REXTOX is likely to underestimate exposure (and risk) from pesticides which are expected to be very mobile in soil. Additionally, there is no account for exposure of pesticides applied by seed treatment or incorporated in granules as well as the ones used as soil sterilants. The models used to calculate loss via spray drift and runoff are similar to those used in registration and pesticide risk assessment (respective formulas are given in [9], page 17-19). Key variables for the calculation of the percentage loss of pesticides via spray drift are spray drift buffer width and spray drift buffer compliance by farmers. Respective key variables for runoff calculation are runoff buffer width and runoff buffer compliance, log K_{ow}, and half-life soil (DT_{50,soil}).

In comparison to the other indicators, REXTOX is a relatively sophisticated and data intensive indicator (see Table 2.1 above). It includes not only variables related to pesticide physico-chemical properties and use, but also different environmental variables (see Chapter 3). Among the environmental variables such as soil type, slope and precipitation only water index is also considered by the two other indicators. The water index stands for the proportion of agricultural area bordered by surface water bodies.

REXTOX calculates exposure values on two levels which are represented by an unscaled and a scaled value. The former reflects the amount of a pesticide likely to end up in surface water bodies originating from the treatment of one typical agricultural hectare. In contrast, the
scaled exposure value takes the real treated area into account. Hence, it reflects the expected loss into water bodies based on the total amount of a pesticide applied.

As for the exposure values REXTOX allows to analyse the exposure:toxicity ratio (i.e. risk) on several levels. First, the specific risk potential per hectare for each pesticide application based on recommended dose rates (label rate) is calculated. Second, based on actual dose rates applied and frequency of application (i.e. number of applications of the same pesticide on the same hectare during the same agricultural season) the specific risk intensity per hectare of each pesticide is calculated. These two levels allow to compare risk in association with recommended and real crop protection practice. Additionally, both levels allow identification of pesticides with a particularly high risk potential.

The third risk level, called simply risk index, takes into account the extent of risk by combining the specific risk intensity of a pesticide with the actual agricultural area treated with the same pesticide (i.e. the consideration of the effective amount of pesticide applied). Dependant on the level (i.e. regional or national or both) and temporal extent of available use data (see Chapter 3) the risk index is useful to track risk trends for each pesticide or all pesticides on a regional and/or national scale. Additionally, risk indices allow to identify risk trends for one crop, specific categories of crops or all crops.

In REXTOX all above mentioned risk indices can be calculated as acute (time scale minutes) or long-term (time scale weeks) values. Acute risk indices correspond to a short-term exposure: LC$_{50}$ ratio. Long-term risk indices are based on a long-term exposure: NOEC ratio. Thereby, long-term exposure is calculated by multiplying acute exposure with a so-called long term factor. This factor indicates the ratio of the weighted average pesticide concentration (calculated on the basis of first-order degradation kinetics requiring DT$_{50,water}$ values) over a certain period (default value of 21 days was considered in correspondence to regular time period of long-term toxicity tests) and the initial concentration (for details see [9]).

2.3 ADSCOR (ADditive SCORing)
ADSCOR is the simplest of the three indicators developed by the OECD Pesticide Aquatic Risk Indicator Expert Group. It is similar to a Swedish indicator used to measure progress in national risk reduction [3]. ADSCOR, in comparison to REXTOX, uses direct values for area treated and toxicity only. All other variables are scored. Hence, ADSCOR is a hybrid scoring indicator.

For a given specific pesticide application ADSCOR first derives single scores for each considered variable contributing to exposure (see Table 2.1 above). In a second step, these scores are simply added up to obtain a total exposure score for a specific pesticide application. This value thereby reflects an exposure score per hectare agricultural area treated (i.e.
unscaled exposure score). To obtain a scaled exposure score the unscaled value is multiplied by the area treated with this pesticide.

Within the scoring process exposure routes are not modelled explicitly but all routes of exposure are considered implicitly.

In general, the scoring procedure involves a division of each variables value range into several risk contribution categories (see Table 2.2 below). A crucial step thereby is the setting of breakpoints between these categories. The OECD Pesticide Risk Indicator Expert Group considered the following aspects for breakpoint setting within their own evaluation of the indicators:

- division of data available into the appropriate number of categories
- assignment of roughly equal numbers of pesticides to each category

The Expert Group stated in their 2000 report [3] that some breakpoint settings have to be adjusted to suit the particularities of national use data. Therefore, breakpoints for applied dose rate and water index were adjusted in order to suit the Swiss pesticide use data (see Chapter 3). For example, the breakpoint setting for applied dose rate was made in order to take into account the frequency of dose rates values within the use data. Thereby, roughly equal number of applications were assigned to each scoring category (see Appendix 1).

In addition to the breakpoint setting the assignment of scoring categories is an important aspect of scoring indicators. Through assignment of different numbers of scoring categories a relative weighting of variables may be achieved. For example, a variable with a high number of scoring categories is weighted as more important in its contribution to pesticide exposure than others having less scoring categories (see also Chapter 4.2).
In ADSCOR five different scoring categories accounting for a scoring range between 0 and 4 (first column) for each variable are possible. For example, the table for the second column showing the breakpoints for applied dose rate, is read as follows: If the applied dose rate is $> 0$ but $\leq 0.003$ then a score of 0 is applied, if the applied dose rate is $> 0.003$ but $\leq 0.012$ then a score of 1 is applied etc. Note that for the variable log $K_{ow}$ the scoring direction is reversed.

Indicator users must change the values for breakpoints for applied dose rate and water index to suit their national/regional particularities [9, 10]. The respective above mentioned breakpoint settings suit the Swiss data set as described in Chapter 3. The breakpoints for the other variables such as $DT_{50, soil}$ and $DT_{50, water}$ were used as originally defined by the OECD Pesticide Aquatic Risk Indicator Expert Group.

By defining different numbers of scoring categories the relative weight of variables may be influenced. Thereby, the weight of a variable increases with a higher number of scoring categories. In this example applied dose rate accounts for 5 categories and therefore has the highest weight. For all other variables only 3 categories were defined as the extreme values such as $1E+12$ or $-1E+12$ respectively (i.e. $\pm 10^{12}$) serve only to complete the table with real numbers. However, such numbers will not be reached by real values.

<table>
<thead>
<tr>
<th>Scores</th>
<th>Applied dose rate [kg/ha]</th>
<th>Avg. frequency of treatment per season</th>
<th>Water Index</th>
<th>$DT_{50, water}$</th>
<th>$DT_{50, soil}$</th>
<th>Photolysis</th>
<th>$\log K_{ow}$</th>
<th>$\log K_{oc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
</tr>
<tr>
<td>4</td>
<td>0.166</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>- $1E+12$</td>
</tr>
<tr>
<td>3</td>
<td>0.044</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>- $1E+12$</td>
</tr>
<tr>
<td>2</td>
<td>0.012</td>
<td>3</td>
<td>4</td>
<td>183</td>
<td>183</td>
<td>$1E+12$</td>
<td>3</td>
<td>1.2957</td>
</tr>
<tr>
<td>1</td>
<td>0.003</td>
<td>1.1</td>
<td>2</td>
<td>60</td>
<td>60</td>
<td>5</td>
<td>2</td>
<td>2.3109</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>- $5$</td>
</tr>
</tbody>
</table>

Similar to REXTOX, ADSCOR calculates different levels of exposure:toxicity ratios. The division of the unscaled exposure score by toxicity leads to the specific risk intensity (i.e. risk resulting of a treatment of one hectare agricultural area with a specific pesticide). A risk index is produced by multiplying the specific risk intensity with the direct value of area treated.

As with REXTOX, it is possible to calculate acute as well as long-term risk indices. The acute risk index is based on the short-term exposure score:LC50 ratio. Likewise, the long-term risk index is calculated by the division of the long term exposure score by NOEC values. It has to be noticed that in ADSCOR contribution of variables referring to pesticide fate are only considered for long-term exposure (see Table 2.1).

Like REXTOX, ADSCOR allows to identify problematic pesticides by analysing specific risk intensities and to display risk indices on different aggregation levels like one crop/several crops, one pesticide/several pesticides.

### 2.4 SYSCOR (SYnergistic SCORing)

SYSCOR is a simplified version of a French indicator using a hierarchical linkage of variables to rank pesticides according to their intrinsic properties, called SIRIS (for System of Integration of Risk with Interaction of Scores) [9, 11].

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Table 2.2: Breakpoint table in ADSCOR

In ADSCOR five different scoring categories accounting for a scoring range between 0 and 4 (first column) for each variable are possible. For example, the table for the second column showing the breakpoints for applied dose rate, is read as follows: If the applied dose rate is $> 0$ but $\leq 0.003$ then a score of 0 is applied, if the applied dose rate is $> 0.003$ but $\leq 0.012$ then a score of 1 is applied etc. Note that for the variable log $K_{ow}$ the scoring direction is reversed.

Indicator users must change the values for breakpoints for applied dose rate and water index to suit their national/regional particularities [9, 10]. The respective above mentioned breakpoint settings suit the Swiss data set as described in Chapter 3. The breakpoints for the other variables such as $DT_{50, soil}$ and $DT_{50, water}$ were used as originally defined by the OECD Pesticide Aquatic Risk Indicator Expert Group.

By defining different numbers of scoring categories the relative weight of variables may be influenced. Thereby, the weight of a variable increases with a higher number of scoring categories. In this example applied dose rate accounts for 5 categories and therefore has the highest weight. For all other variables only 3 categories were defined as the extreme values such as $1E+12$ or $-1E+12$ respectively (i.e. $\pm 10^{12}$) serve only to complete the table with real numbers. However, such numbers will not be reached by real values.

<table>
<thead>
<tr>
<th>Scores</th>
<th>Applied dose rate [kg/ha]</th>
<th>Avg. frequency of treatment per season</th>
<th>Water Index</th>
<th>$DT_{50, water}$</th>
<th>$DT_{50, soil}$</th>
<th>Photolysis</th>
<th>$\log K_{ow}$</th>
<th>$\log K_{oc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
<td>Is $&gt;$</td>
</tr>
<tr>
<td>4</td>
<td>0.166</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>- $1E+12$</td>
</tr>
<tr>
<td>3</td>
<td>0.044</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>$1E+12$</td>
<td>- $1E+12$</td>
</tr>
<tr>
<td>2</td>
<td>0.012</td>
<td>3</td>
<td>4</td>
<td>183</td>
<td>183</td>
<td>$1E+12$</td>
<td>3</td>
<td>1.2957</td>
</tr>
<tr>
<td>1</td>
<td>0.003</td>
<td>1.1</td>
<td>2</td>
<td>60</td>
<td>60</td>
<td>5</td>
<td>2</td>
<td>2.3109</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>- $5$</td>
</tr>
</tbody>
</table>

Similar to REXTOX, ADSCOR calculates different levels of exposure:toxicity ratios. The division of the unscaled exposure score by toxicity leads to the specific risk intensity (i.e. risk resulting of a treatment of one hectare agricultural area with a specific pesticide). A risk index is produced by multiplying the specific risk intensity with the direct value of area treated.

As with REXTOX, it is possible to calculate acute as well as long-term risk indices. The acute risk index is based on the short-term exposure score:LC50 ratio. Likewise, the long-term risk index is calculated by the division of the long term exposure score by NOEC values. It has to be noticed that in ADSCOR contribution of variables referring to pesticide fate are only considered for long-term exposure (see Table 2.1).

Like REXTOX, ADSCOR allows to identify problematic pesticides by analysing specific risk intensities and to display risk indices on different aggregation levels like one crop/several crops, one pesticide/several pesticides.

### 2.4 SYSCOR (SYnergistic SCORing)

SYSCOR is a simplified version of a French indicator using a hierarchical linkage of variables to rank pesticides according to their intrinsic properties, called SIRIS (for System of Integration of Risk with Interaction of Scores) [9, 11].
Unlike ADSCOR, SYSCOR scores each variable considered to contribute to exposure of pesticides into surface water (see Table 2.1 above). The only unscored variable in SYSCOR is *toxicity*. Like in ADSCOR, in SYSCOR the exposure process is not modelled explicitly but different routes of exposure are implicitly considered within the scoring process.

SYSCOR is a complex indicator as a hierarchical scoring system is applied which considers both, ranking of variables according to their importance in contributing to exposure and interactions between related variables. On one hand, the consideration of a synergistic contribution of variables to risk seems to provide a better approximation of real risk than the simple addition of scores like in ADSCOR, because it aims at reflecting the current scientific knowledge about synergies of environmental processes. On the other hand, the multilevel concept in SYSCOR hardly allows program adjustments since this indicator is quite intransparent.

Unlike ADSCOR and REXTOX, SYSCOR does neither calculate an exposure value per individual hectare nor the specific risk intensity of pesticides (i.e. exposure score per hectare/toxicity). SYSCOR deals with a *scaled exposure* score from the very beginning of the scoring process as the *agricultural area treated* is one of the top ranked variables in its exposure hierarchy.

A second aspect in which SYSCOR significantly differs from the other two indicators is its design to calculate only *short-term exposure scores* and *acute risk indices*.

SYSCOR was revised twice in 2001. Further modifications will be done according to the French program developers.

### 2.5 Relation of the three OECD pesticide aquatic risk indicators to the existing range of risk approaches

The OECD Pesticide Aquatic Risk Indicator Expert Group assessed the three developed aquatic risk indicators according to their representativeness of existing national pesticide indicators. They concluded that the selected indicators cover the range of existing ones with respect to most of their characteristics. Some of their important findings are mentioned below [9]:

- the OECD indicators are more complex than many existing approaches.
- unlike REXTOX, ADSCOR and SYSCOR are not consistent with regulatory risk assessment as they produce a pesticide exposure score instead of an estimated environmental concentration of pesticides.
- unlike some of the existing approaches, bioconcentration factors were not considered for REXTOX and SYSCOR. In ADSCOR the bioaccumulation potential of pesticides is taken into account by using log K_{ow} as scoring variable contributing to exposure.
the main omission of the OECD indicators in comparison with existing approaches are found in ADSCOR and SYSCOR. Some existing scoring indicators do account for linear and non-linear scoring functions. In contrast, ADSCOR uses mostly step functions while SYSCOR allows non-linear scoring but in a different way than existing approaches.

in contrast to single-pesticide risk assessment methods, any of the model indicators can provide an overview on the regional/national pesticide risk situation.

the OECD indicators do use actual use data and not just worst case values as generally applied in risk assessment. Hence, trouble spots (i.e. problematic pesticides or uses of pesticides) can be identified.

unlike most of the existing approaches the model indicators are risk and not hazard indicators as they include applied dose rates, application factors and some environmental variables.

out of four existing methods to combine exposure and toxicity such as «no combination», «division/multiplication», «addition», and «fuzzy logic» only one is used by all three OECD indicators (= «division»).
3 Availability and Quality of Input Data

Availability, reliability, and completeness of input data are mainly determining the quality of the indicator results. All three indicators evaluated in this project combine use data with pesticide properties. REXTOX additionally integrates site specific information. In this Chapter importance, availability and quality of input data are discussed.

3.1 Pesticide Data

For about 150 active substances data concerning physico-chemical properties, environmental behaviour and eco-toxicology had to be compiled. Especially data for older pesticides were not always available. In the following paragraphs we specify situation and problems with data selection.

3.1.1 Sources

In general, data form the Pesticide Manual [12] or from the British or German databases (provided within the OECD pilot project) were used. In case of inconsistencies or missing data, additional handbooks [13] or registration dossiers as well as specific articles [14-19] were consulted. In few cases data were estimated based on properties of similar compounds.

3.1.2 Physico-chemical properties

Usually the physico-chemical parameters solubility and K_{ow}-values are available, but for substances with a pK_{a}-value in an environmentally relevant pH-range, these parameters can be strongly pH-dependent.

*Example:* The water solubility of the herbicide triasulfuron varies from 32 mgL^{-1} at pH 5 to 13’500 mgL^{-1} at pH 8.4.

The parameters may further depend on ambient temperature. If available, we used data measured at pH 7 and at 20-25 °C, which of course, do not suit actual environmental conditions but are standardized.

3.1.3 Environmental fate and behaviour

Degradation pathways, half-lives or transport of compounds in the environment as well as the relative importance of different processes are strongly dependent on the conditions such as soil type, climate, characteristics of surface waters or rain events, etc. To chose one single fixed value - e.g. for degradation rates - always means a rough simplification, particularly since even measurements in standardized systems lead to significant variations as well. Some specific comments on the individual parameters are given below.
**Half-life in soil DT\textsubscript{50,soil}**

For most active ingredients soil degradation rates are available, but heavily dependent on the test systems used (e.g. field data compared to laboratory test systems). Values differing by a factor of 10 or 100 are within the usual limits. For the «pesticide table» we used median or average values from various sources if possible.

**Half-life in water DT\textsubscript{50,water}**

This parameter should represent the degradation in natural surface water, which is available only for few active ingredients. In addition this parameter is strongly dependent on the observed system, since processes like flushing, sedimentation, light-induced transformation, microbial activity or volatilisation may contribute to the overall dissipation. Usually hydrolysis rates are published, but do not represent environmental behaviour. Furthermore, in many cases hydrolysis is strongly pH-dependent.

*Example: The insecticide mevinphos is hydrolysed with a half-life of 120 d at pH 6 and of 35 d at pH 7, respectively.*

The OECD-Expert Group suggested the use of degradation rates measured in sediment/water systems instead. In our opinion this is not appropriate for catchment area scenarios as in the case of Swiss lakes. Moreover sediment/water degradation rates are only available for recently developed pesticides or compounds with recently prepared registration dossiers (such as for reevaluation). The lack of DT\textsubscript{50,water} values was recognized by the OECD-Expert Group as well as by the participants of the OECD pilot project but is still an unsolved problem ([9] and discussions at the 2\textsuperscript{nd} pilot project meeting, April 18-19 2001 Paris).

In the few cases where we calculated long-term risk indicators, we used DT\textsubscript{50,water} values form the British or German databases, although the origin of these data was not always documented. In most cases we tested only acute risk indicators, where degradation rates in water are not required.

**Photolysis in water**

For many substances photolytic degradation rates are published in hand books or literature, but the characterization of experimental conditions (such as wavelength range, light intensity or layer thickness) is insufficient.

*Example: in the Pesticide Manual [12] a photolysis half-life of 2.6 d is given for atrazine. This value was adopted for the British and the German databases, although it was determined with a mercury lamp (\(\lambda_{\text{max}}\) 254 nm). However, under natural sunlight atrazine is not photolyzed.*

In addition, photolysis rate constants under natural conditions are strongly dependent on the system (residence time, composition of surface water, latitude, season etc.). For various pesticides photolysis is an important degradation pathway which should not be neglected, but
it can hardly be integrated in an indicator, due to insufficient data. For that reason and because photolysis is only considered in ADSCOR, we set all values for photolysis half-life equally to 50 days.

3.1.4 Toxicity values

Toxicity values are crucial since they are used as a divisor in the indicator calculation. Uncertainties or mistakes may strongly affect the value of the indicator as well as the relative contribution of single pesticides to overall risk. According to Lewis [20] EC50 values from algae tests depend strongly on the test system and species used. Therefore, results may easily differ by factors up to 2000. In fact, some of the data found in the British and the German databases or published in the literature differed remarkably for many substances. Especially for algal toxicity, factors up to 1000 are frequently found, in some cases even up to 10^9. (Discrepancies for fish or daphnia toxicity are significantly lower.)

Example: Algal acute toxicity of the herbicide bifenox is 0.000175 mg L^{-1} according to the German database, whereas the value in the British database is 130 mg L^{-1}. No value is published in the Pesticide Manual.

In addition, toxicity endpoints may differ for different compounds: in many cases there are no EC50 or LC50 values published but NOECs (No Observed Effect Concentrations). The duration of the tests and the related endpoints are not consistent as well (e.g. EC50 (24h) versus EC50 (96h)). Values for chronic or long term toxicity are not available at all for many active ingredients. Sometimes not exact values but minimal limits (e.g. NOEC (96h) > 100mg/L) are given. In opposite to the OECD Expert Group, we think that inconsistent endpoints are problematic, because the weight of individual pesticides in aggregated indicators is affected.

Because of insufficient long term data we multiplied short term toxicity values with a factor of 0.01 instead. The distinct uncertainties and problems with availability of toxicity data have to be taken into account when interpreting the indicators!

3.1.5 Metabolites, byproducts and precursors of active ingredients

Metabolites of active ingredients as well as byproducts of commercial formulated products may act as environmental risk and/or have a pesticide impact. Both, metabolites and byproducts are not included in the indicator models.

Examples can be found among triazines: a) desethylatrazine, which is a metabolite of atrazine and shows herbicidal activity, is detected in Swiss lakes in concentrations similar to those of atrazine. b) Although the use of propazine is not authorized, it is measured in surface waters, likely originating from impurities in atrazine formulations.

In many cases not the active ingredient itself but a precursor (e.g. an ester) is applied. In general, such precursors are rapidly hydrolysed in the environment. It is misleading to
introduce substance properties of the applied precursor, because in fact, the «degradation product» is the active substance, often with longer half-lives in the environment and/or higher mobility in soil. Data of such degradation products are not easily available for all substances but were introduced into the pesticide table instead of the applied precursor, if possible.

Example: Fluorglycofen-ethyl, which is the applied substance is hydrolysed in soils to fluoroglycofen with a half-life of 0.5 d. Fluoroglycofen is further degraded to acifluorfen (not authorized in Switzerland) with a DT$_{50,soil} = 1$ d. In this case, in the data set for «fluorglycofen» data of acifluorfen were used.

3.1.6 Remarks on effects of pesticide data variability and improvement of databases

Investigations of the Danish pilot project participants showed, that risk time trends produced by ADSCOR and REXTOX were robust against variability of input data. Although absolute indicator values were strongly dependent on the selected input data, the trends over nine years, considering 150 pesticides on a national level, was not affected by the use of various input data sets [21]. Nevertheless, the trends over short time periods or the indicator results generated on lower aggregation levels are depend on the selection of input data. The Danish evaluations concerned only acute risk indicators. The OECD expert group recognized that the varying availability of data (namely DT$_{50,water}$ and longterm toxicity) led to indicator results which were clearly not representing «real-world risks» [9].

The reliability of pesticide data could be improved by using average or median from numerous values published in handbooks, literature and from registration procedures. Although this would need big efforts, it could be facilitated by international sharing of information.

3.2 Use Data

3.2.1 Availability of use data

Generally use data can be attained from farmer surveys or estimated from sales data. Most of the pilot project participants worked with sales data (Denmark, Germany, Norway, Japan). If pesticide use should be related to respective cultures and application time, the estimation procedure is time consuming and complex [9]. As the example of Norwegian and Danish data showed, estimates from sales data may lead to artifacts: e.g. it was observed, that after announcement of a new pesticide tax, the amount of sold pesticides increased drastically, whereas in the year of the tax implementation farmers bought less, because they were using their stocks [21, 22]. In general, use data estimated from sales data, are on a national level and can therefore not be used for a comparison between regions. As concluded by the Expert Group, use data from farmer surveys are preferable [9].

Use data for the Swiss contribution to the indicator evaluation were attained from a farmer
survey in three regions (the catchment area of Greifensee, Baldeggersee and Murtensee) in 1997 and 1998, carried out by LBL (Landwirtschaftliche Beratungszentrale Lindau) and SRVA (Service Romand de Vulgarisation Agricole). Questionnaires were sent to about 300 farmers (15% of all farmers in these regions). Criteria for sample selection were farming system (integrated production (IP), organic farming (Bio) or conventional farming), area of farmland, and crops. Results from these samples were extrapolated to whole catchment area using the AGIS database (AGropolitic Information System of the Swiss Federal Office for Agriculture). Main problems for the institutions in charge with the survey were low response of farmers, time consuming evaluation and extrapolation of survey results, and small sample sizes for some special crops, e.g. wine and orchards. Until now, no statistical evaluation of the reliability of sample selection or extrapolation is available. For more detailed description of the survey see respective reports [23, 24]. An evaluation of the survey methodology was done by Heberle [25], who found, that the surveys were in general accordance with the OECD Guidelines for the Collection of Pesticide Usage Statistics [26]. The selection of the 3 regions for surveys seems reasonable, because farming is relatively intensive in all three regions, but an extrapolation from the survey regions to a national level would probably not be appropriate.

3.2.2 Selection of crops and pesticides

In general, the selection of crops and pesticides considered for indicator calculation is critical, as also active ingredients used in small amounts or minor on crops may significantly contribute to the overall risk. E.g. German data showed, that the selection of the top 15 herbicides was not appropriate and was misleading. The risk indices of the top 15 herbicides showed a distinct peak in 1994 compared to 1987 and 1998. The peak could be related to a single herbicide (bifenox), which had a very low algal LC$_{50}$ value and was in top the 15 in 1994 but not in 1987 or 1998, although the totally applied amount of bifenox was similar in all three years [27].

For the Swiss indicator validation a selection of the most important crops was made. The use data of the following arable crops were applied:

- Cereals (oat, wheat, triticale, barley, rye, German wheat)
- Corn
- Rapeseed (Canola)
- Potato
- Sugar and fodder beet
- Soya
- Permanent pastures, grassland
These crops covered a major part of all pesticides applied in the three regions and a major part of the agricultural land, which, according to survey data, is treated with pesticides (see table 3.1).

**Table 3.1: Percentage of total pesticide use and treated agricultural land, covered by the selected crops in the three regions, and the absolute treated area in 1997 (based on the farmer survey).**

<table>
<thead>
<tr>
<th>Region</th>
<th>% of pesticide use</th>
<th>% of treated area</th>
<th>treated area [ha]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greifensee</td>
<td>92 %</td>
<td>93 %</td>
<td>4388</td>
</tr>
<tr>
<td>Baldegersee</td>
<td>86 %</td>
<td>98 %</td>
<td>3027</td>
</tr>
<tr>
<td>Murtensee</td>
<td>86 %</td>
<td>88 %</td>
<td>28397</td>
</tr>
<tr>
<td>Over all regions</td>
<td>86 %</td>
<td>90 %</td>
<td>35812</td>
</tr>
</tbody>
</table>

Although the contribution of orchards and vineyards to the total amount of applied pesticides is small, they would have been of interest for the indicator validation due to differing application methods and pesticide mix. The consideration was not possible because of too small sample sizes in the survey (see above).

Furthermore the following simplifications were made:

- Areas of each crop were subsumed for every region and treated as a unit, what seemed appropriate, since use data were attained by extrapolation from surveys.

- The applied dose rate (ADR) was calculated for each active ingredient per crop and region by division of the respective totally applied amount by the total area of the respective crop. Hence, it was assumed, that all fields of each crop are treated uniformly. REXTOX is insensitive to this simplification, where as the results of ADSCOR are affected, since ADR is a scoring variable and the basic area treated (BAT) is used as multiplication factor (see also paragraph 4.3.2).

- As a consequence of ADR calculation, the actual frequency of treatment (AFT) was set to 1 for all pesticides, and hence, the total dose was assumed to be applied at once. Again, REXTOX would not be affected by the assumption, since the model recalculates the amount by multiplication of ADR with AFT and the area treated. In ADSCOR AFT is a scoring variable so that, effects on the results cannot completely be ruled out.

- BAT was calculated for each crop by multiplication of the crop area with the percentage of treated area from the survey. As a consequence of the previous assumption (AFT = 1), the cumulative treated area (CAT) for every crop was the same as BAT.

- The recommended dose rate (RDR), which could be taken from instruction sheets was not considered (ADR was listed instead). The indicator results are not influenced by this simplification, but the option to calculate the «potential risk» with REXTOX is lost.
Since only arable crops were considered, the application method was set throughout to «ground spray» (exception: for applications in permanent green land, «granular incorporated» was used for some pesticides). Furthermore buffer width was set to 3 m for all applications. Even with these simplifications the usage table contained more than 1’000 entries for only two years. If use data are available the consideration of each single application is possible but would lead to an enormous amount of data.

About 150 active ingredients were considered. Not considered were pesticides from natural sources such as e.g. azadirachtin A, bacillus thuringiensis, mineral oil, detergents used as pesticides and inorganic compounds such as sulfur or copper, for which physico-chemical properties and/or toxicity values cannot be defined as required by the indicator.

3.2.3 Importance of use data

In Switzerland the sales statistics of the Swiss association of the chemical industry (SGCI) is the only source for sales data. In the SGCI statistics only the top 20 active ingredients are itemized, for the remaining compounds sales data are only available in aggregated form (e.g. compound classes). Neither the completeness nor the level of detail of sales data is sufficient for even simple risk indicators. Therefore, all indicator evaluation was done with the survey data for 1997 and 1998, which were the only available data (survey data for 1999 were not yet processed until the end of the project in October 2001).

Obviously, time trends in pesticide use or pesticide risk cannot be observed without reliable, complete and detailed use data. Depending on the problem formulation, different levels of detail concerning crop, time, or geographic description of pesticide application are needed.

3.3 Characterisation of Regions

Of the three tested risk indicators, only REXTOX considers various site variables (slope, organic carbon in soil, soil type, precipitation, average water depth and water index), the other indicators only use water index. A proper determination of these site variables is time consuming and can be performed best by using a geographic information system (GIS). The values used in our work were rough estimates. This seemed to be appropriate, since average values over entire regions are used, and hence, the regions properties differed very little. In fact the sensitivity of REXTOX against the site variables is small (see paragraph 4.2). Nevertheless, the use of site specific properties give the possibility to look closer at regional differences (in case detailed use data are available) or might receive more weight in a further developed or recalibrated indicator.

In table 3.2 the actual settings for site variables are listed. Table 3.3 gives additional information about the three regions, which was not used in the indicators.
Table 3.2: Actual Settings for site variables

<table>
<thead>
<tr>
<th>Region</th>
<th>Soil type</th>
<th>% OC</th>
<th>Water Depth [m]</th>
<th>Water Index</th>
<th>Slope [%]</th>
<th>Precipitation [mm]</th>
<th>Buffer Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greifensee</td>
<td>loamy</td>
<td>2</td>
<td>1</td>
<td>1.9</td>
<td>7.5</td>
<td>8.5</td>
<td>1</td>
</tr>
<tr>
<td>Baldeggsee</td>
<td>loamy</td>
<td>2</td>
<td>1</td>
<td>1.7</td>
<td>9</td>
<td>8.1</td>
<td>1</td>
</tr>
<tr>
<td>Murtensee</td>
<td>loamy</td>
<td>3</td>
<td>1</td>
<td>3.2</td>
<td>7.5</td>
<td>8.2</td>
<td>1</td>
</tr>
</tbody>
</table>

- From soil maps (Bodenkarte der Schweiz 1:25’000, Hrsg. Eidg. Forschungsanstalt für landw. Pflanzenbau FAL, Zürich-Reckenholz) it was concluded, that in all three region loamy soils were predominant.
- The percentage of organic carbon in soils was roughly estimated from soil maps.
- The water depth was assumed to be 1m. Since the same value was set in all regions, it would not affect the indicator results.
- For water index the percentage of virtual fields of 1 ha size bordering surface water was estimated, which would be identical to 100m waterside per 1 hectare agricultural land. The length of waterside was measured on a map (Landeskarte der Schweiz 1:50’000, Schweizerische Landestopographie).
- The slope was roughly estimated from soil maps.
- Precipitation was taken from [28, 29]. The values represent an average daily rain event [mm] during the application period.
- Full compliance of buffer width by farmers was assumed, which, according to staff at regional agricultural extension services, is reasonable.

Table 3.3: Additional information about regions

<table>
<thead>
<tr>
<th></th>
<th>Greifensee</th>
<th>Baldeggsee</th>
<th>Murtensee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment area [km²]</td>
<td>160</td>
<td>160</td>
<td>693</td>
</tr>
<tr>
<td>Inhabitants</td>
<td>100’000</td>
<td>10’000</td>
<td>75’800</td>
</tr>
<tr>
<td>Agricultural land [km²]</td>
<td>119</td>
<td>108</td>
<td>493</td>
</tr>
<tr>
<td>Lake volume [m³]</td>
<td>1.5E8</td>
<td>1.7E8</td>
<td>5.5E8</td>
</tr>
<tr>
<td>Lake surface [m²]</td>
<td>8.5E6</td>
<td>5.2E6</td>
<td>22.8E6</td>
</tr>
<tr>
<td>Mean residence time [y]</td>
<td>1.1</td>
<td>3.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>
4 Strategies and results of indicator validation

4.1 General considerations about risk indicator validation
Risk per se is rather a theoretical concept than a concrete variable, and is therefore not measurable in the real world. Hence, validation of risk indicators has to be carried out indirectly. This can be done by different complementary approaches:

**Statistic approach**
The investigation of robustness and statistic reliability of the risk indicators was a main contribution of the Danish pilot project participants. They focused on the examination of variation in temporal risk trends and the sensitivity of trends to variability in input data. Some of the results are quoted in chapter 3, for more detail see the respective report [21]. It should be noted, that this approach provides useful information about statistic soundness, but does not clarify the meaningfulness or plausibility of an indicator.

**Comparing indicators**
Norway and Denmark compared the three indicators with their own national risk indicators. In fact they found similar risk trends for ADSCOR, REXTOX and the Norwegian indicator or the Danish indicators «Load Index» and «Frequency of Application», respectively, if long time periods and highly aggregated levels were evaluated [21, 22]. If different indicators show matchable temporal risk trends this may increase their credibility but primarily indicates that they are driven by the same variables and does not prove necessarily their accuracy.

**Plausibility testing**
Testing the plausibility and accuracy of the indicators was the main focus of our validation work. Three main approaches were chosen:

- Sensitivity analysis. The sensitivity of the indicators to input variables was evaluated.
- Reaction of the indicators to hypothetic scenarios. Scenarios, such as substitution of active ingredients or changes in agricultural practice were calculated, the respective reaction of the indicator results were rated and discussed with experts. In addition some exemplary calculations were made.
- Comparison of indicator results with monitoring data. The ranking of long-term exposure values, calculated by the indicators for selected pesticides was compared to relative concentrations, measured in Lake Greifensee at EAWAG [24, 30, 31].

In principle, plausibility testing is complicated by the following major factors: First, results of such indicator calculations can only be understood and validated at a low aggregation level.
Because the three OECD indicators were primarily designed to study long term risk trends on a regional or national level, and not to study single active ingredients or crops, such considerations have their limitations. Second, the assessment of sensitivity and of the reaction to assumed changes (scenarios) is dependent on knowledge and opinion of experts and cannot be done objectively. In addition, one has to bear in mind, that «real risk», as above mentioned, can only be approximated. Hence, indicators in general do not claim to be linearly related to «real risk» but they allow to examine rough trends or rankings of pesticides or crops in connection with risk.

Nevertheless, it is our belief that such validation procedures are essential because the basic modules and some qualitative aspects of the results of the indicators have to be rationalized to assess their usefulness and validity.

4.2 Sensitivity Analysis
To understand each variables’ relative impact on the calculation of pesticide exposure values, a sensitivity analysis for each indicator was conducted. By this, not only the relative weighting of variables but also the rationale behind each indicators’ concept on how the different factors contribute to pesticide exposure into surface water bodies could be reviewed. An exemplary illustration of sensitivity is given in Chapter 4.3 where different agricultural scenarios are presented.

4.2.1 Procedure
A simple form of sensitivity analysis was considered to be appropriate to highlight the above mentioned aspects. Thereby, values of variables contributing to exposure (see Table 2.1) were varied respective and the respective exposure values (\(=\exp_{\text{var}}\)) were calculated for each change in variables. Finally, the percent deviation of the \(\exp_{\text{var}}\) from the original exposure value (\(=\exp_{\text{org}}\)) which is based on the original variable settings as presented in Chapter 3 was analysed.

For the analysis of REXTOX and ADSCOR the 1998 regional aggregated pesticide scaled exposure value of Greifensee (\(=\exp_{\text{org}}\)) was taken as reference (see Chapter 2). This value simply reflects the sum of all exposure values produced by 79 pesticides, accounting for 155 crop applications in 1998.

Sensitivity analysis of the revised SYSCOR version was done on the basis of the French input data accounting for totally 167 pesticide applications in five regions (this data was part of the revised September 2001 program version; see Chapter 2.4).

It should be noted that the impact of the variable \textit{applied frequency of treatment} in ADSCOR and SYSCOR as well as of \textit{application methods} except \textit{aerial application} were not tested.
This kind of analysis allowed to investigate the influence and weight of single variables only. Synergistic sensitivity was not analysed except for the application method *aerial application* in connection with buffer zone widths.

### 4.2.2 Discussion of sensitivity analysis

**REXTOX**

The sensitivity analysis of REXTOX was made for 14 variables. The indicator is mainly driven by both, pesticide use (see Figures 4.1) and environmental variables (see Figure 4.2) whereby the following are most important: *basic area treated (BAT)*, *applied dose rate of pesticide (ADR)*, *spray drift buffer compliance (SBC)*, *spray drift buffer width (SB)*, *water index* (i.e. proportion of agricultural area bordered by open water bodies), and *water depth*. Thereby, the mathematical product of *ADR* and *BAT* reflects the total amount of each pesticide applied, which correlates positively linear with exposure value. The same kind of relationship between exposure changes and variable is also true for *water index* reflecting that the higher the proportion of agricultural area bordered by water bodies, the higher the expected exposure of pesticides. In contrast, the inverse and non-linear impact of the *water depth* of surrounding water bodies which accounts for dilution (multiplier factor >1).

The high weight of *spray drift buffer width* and *spray drift buffer compliance* in comparison to the same variables for runoff is striking. If compared with respective values for runoff, it is very likely that the relative influence of spray drift buffer width is overestimated. A minimal change of a spray drift buffer width from originally 3m to 3.6m for example (multiplier value = 1.2; Figure 4.1) would lead to a total pesticide exposure decrease in surface water of about 25%. In contrast, the same scenario for runoff buffer width would only result in an exposure decrease of about 2%. It is important to note, that subsequently the relative weight of loss of pesticides via spray drift compared to runoff is likely overestimated since spray drift buffer width is a key variable in calculating loss via spray drift (11). According to literature and own field investigations (EAWAG) runoff seems to be more relevant in loss of pesticides into water bodies than spray drift (excluding aerial application and improper applications of pesticides). An illustration and further discussion of this aspect are presented in Chapter 4.3.6 (see Table 4.8).

Due to the low relative weight of runoff versus spray drift as input process, in REXTOX, the physico-chemical properties of pesticides do have a comparable low weight on exposure except for *half-life in water* (*DT_{50,water}*). *DT_{50,water}* is considered for the calculation of long term exposure (see Chapter 2.2) which is remarkably decreasing with shorter half-life in water (see Figure 4.1).

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Figure 4.1 and 4.2: Sensitivity details of REXTOX

Abbreviations: SB / RB = spray drift and runoff buffer width respectively; GS = ground spray application of pesticides; BAT = basic area treated in Greifensee region in 1998; SBC / RBC = spray drift and runoff buffer compliance by farmers respectively (e.g. 1 = 100%, 0.5 = 50%); ADR = applied dose rate of pesticides; %OC = content of organic carbon in soil

The figures show the effects of changes of variables’ values on the pesticide exposure value, i.e. the percent deviation of the exp_var (basis = varied variable settings by multiplier value) from the original exposure value exp_org (basis = original variable settings of Greifensee region in 1998). For example, a doubling of applied dose rate results in a doubling of the respective exposure value (% difference exp_var/exp_org = 100%).

In REXTOX, pesticide use variables such as BAT, ADR, spray drift buffer width and compliance as well as the environmental variables water index and water depth represent the main driving forces.
Besides water index and water depth further environmental variables such as precipitation and slope do have comparatively little effect on exposure what, as mentioned above, is due by the relative low weighting of runoff in REXTOX. Hence, increasing the weight of runoff according to scientific findings would increase the relative weight of these variables.

It should be mentioned that the importance of the environmental variables may be neglected as long as national use data are considered because there will be only one mean value for each variable for the entire country and use data set. However, if regional use data are available, environmental variables come into effect, as they allow to differentiate pesticide exposure in connection with specific regional parameters.

Additionally, an exceptional high sensitivity of REXTOX on aerial application of pesticides compared to ground spray application was found. This relative high weighting is due to the assumption in REXTOX that aerial application leads to a loss of 100% of applied dose rate via spray drift. Although a considerable amount of pesticides will directly end up in water through aerial application, it is questionable whether the loss via spray drift accounts for 100% as not the entire amount applied will be sprayed on water bodies. It should be noted that in REXTOX the total loss of a pesticide is calculated by \( \text{loss} = (\% \text{ spray drift} + \% \text{ runoff}) / \text{water depth} \) whereby this value is subsequently multiplied by applied dose rate. Hence, if water depth is considered as 1 as in the Swiss regional data set, in REXTOX, total loss of pesticide accounts even for more than 100% of applied dose rate because in addition to the calculation of a 100% loss via spray drift a loss via runoff is calculated.

**ADSCOR**

The sensitivity analysis of ADSCOR was done for 11 variables as shown in Figures 4.3 and 4.4. The most obvious feature in Figure 4.3 is the high and linear weight of basic area treated which simply reflects its incorporation as «direct value variable» within this hybrid scoring indicator (see Chapter 2.3).

Changes in spray drift as well as in runoff buffer width do only lead to one distinct change in exposure value (see Figure 4.3). As long as the spray drift buffer width is \( \leq 1 \text{m} \) the exposure of pesticide (exp_var) is about 25% higher than for a buffer width > 1m. Further increase of buffer width leads to no additional decrease. In case of the runoff buffer the respective limiting value is 0.5m. The rationale behind this one level dependency is the assumption that not the real size of a given buffer zone but the compliance of the farmers with it is the crucial factor for the decreasing or increasing effect of this water protective agricultural measure. Figure 4.3 displays only the effects of partial compliance by farmers with existing buffer zone widths (i.e. 3m) on exposure values because in the underlying Greifensee data (exp_org) full compliance was assumed.
ADSCOR: sensitivity on variables of pesticide use and on water index

Fig. 4.3

ADSCOR: sensitivity on variables of pesticide properties

Fig. 4.4

Figures 4.3 and 4.4: Sensitivity analysis ADSCOR

Abbreviations: SB / RB = spray drift and runoff buffer width respectively; AE = aerial application of pesticides; GS = ground spray application of pesticides; BAT = basic area treated in Greifensee region in 1998; SBC / RBC = spray drift and runoff buffer compliance by farmers respectively; ADR = applied dose rate of pesticides

The figures show the effects of changes of variables’ values on pesticide exposure, i.e. the percent deviation of the exp var (basis= varied variable settings by multiplier value) from the original exposure value exp org (basis= original variable settings of Greifensee region in 1998). For example, a doubling of applied dose rate results in an increase of the respective exposure value of about 9%.

BAT is the main driving force in ADSCOR. Striking, the two level values of exposure only if runoff buffer or spray drift buffer width are varied which is due to the assumption that the compliance by farmers with buffer zones is more important than buffer width. It should be noted that changes of the value of log Kow accounts for two exposure processes, bioaccumulation and runoff, which do have inverse effects on exposure.
ADSCOR accounts for buffer zones in connection with aerial application of pesticides. Lack of a buffer zone leads to an increase of pesticide exposure of about 78%. Consideration of a runoff buffer (limiting value 0.5m, see above) results in lower exposure change of +52%. If both, runoff and spray drift buffer are applied, no difference between aerial and ground spray application can be detected (assuming farmers compliance with buffer zones is 100%). This result is based on the assumption that there is an appropriate buffer width regulation to equal effects of aerial or ground spray application of pesticides.

Unlike REXTOX and SYSCOR, ADSCOR considers the variable $\log K_{ow}$ twice. On one hand it accounts for the estimation of the runoff potential ($\log K_{oc}$ value) of pesticides. On the other hand $\log K_{ow}$ is considered as bioaccumulation factor. As a result, the increase in $\log K_{ow}$ for example accounts for both, an increasing score for bioaccumulation and a decreasing score for runoff potential (dependant on respective breakpoints the decreasing or increasing effect is stronger). Hence, the curve for $\log K_{ow}$ in Figure 4.4 has a extraordinary shape because no clear separation of different processes like transfer of pesticides into water and bioaccumulation is made. The consideration of measured values for $K_d$ instead of indirect calculated $K_{oc}$ values, where available, would likely lead to a more sophisticated view (see Chapter 3). All in all, the account for bioaccumulation within the given approach of exposure:toxicity ratio is questionable from two points of view. First, as long as risk target organisms are not part of the higher food chain such as fish-eating mammals for example the integration of bioaccumulation makes sparsely sense. Second, the accumulation process depends on a time factor which is not considered within the indicator. An appropriate integration of bioaccumulation would likely require an additional sub-model as mentioned by the OECD Expert Group [9].

In general it has to be noticed that the sensitivity of scored variables is driven by two main factors:

- impact level of scoring variable

A variable may be linked to regional data or to use data (e.g. each pesticide application; see Chapter 3). The variable water index for example is considered as regional variable. If a change of its value leads to a change of the scoring category, each pesticides exposure value will be affected to the same extent by adding or subtracting a score to each pesticides added up score (see Chapter 2).

In contrast, applied dose rate is a typical pesticide related variable. A doubling of the rate for each pesticide within the sample does not cause a change in scoring category for all pesticide as some values still remain within the range of the same category. Hence, the impact on the regional exposure value ($\text{exp}_{\text{val}}$), accounting for $\approx +9\%$ is not as significantly as the doubling of the value for water index, leading to an exposure increase of $\approx 26\%$ (see Figure 4.3).
The different impact levels are reflected by the specific shape of the respective curves in Figure 4.3. The sensitivity curve of a regional scoring variable is a step function as there is only one exposure value corresponding to each breakpoint of the variable with no intermediate values. In contrast, the curve for a pesticide related scoring variable is a smooth function due to aggregation of exposure values for many pesticides.

- breakpoint setting and number of scoring categories

The setting of breakpoints is a critical step as previously mentioned in Chapter 2.3. One may influence the weight of variables by variation of the number of scoring categories. As shown in Figure 4.3 the sensitivity on changes in applied dose rate (ADR) is higher than for half-life in soil (DT_{50,soil}) or log K_{ow} for example. The different weight is due to the wide range of scoring categories in ADR accounting for scores from 0 to 4 compared to the small scoring range from 0 to 2 for log K_{ow} and DT_{50,soil} respectively (see Table 2.2, Chapter 2).

**SYSCOR**

The sensitivity analysis of 10 variables of the latest SYSCOR version (see Chapter 2.4) is displayed in Figure 4.5. It revealed the following aspects which are likely program errors:

- the consideration of aerial application of pesticides in combination with changing values for buffer zones widths shows a direct instead of an inverse correlation of the buffer zone width and changes in exposure value (exp\_var). No accounts for buffer zones lead to an increase of pesticide exposure of ≈ 19% while the account for a spray drift as well as runoff buffer zone leads to an even higher increase of about 40%.

- no sensitivity on changes in cumulative area treated (CAT), spray drift and runoff buffer width in connection with ground spray application of pesticides could be observed. This result suggests that a) any area, irrespective its size, treated with the same applied dose rate would lead to the same exposure of a pesticide in water and b) buffer zones do have no influence on pesticide exposure.

- referring to the variable water index, one particular aspect has been observed. Although two breakpoints of the variable were passed by variation of its original value of 0.15 only one change in exposure value was observed (representing passing of the first breakpoint).

- an increase of the organic carbon content in soil (OC%) leads to an increase in exposure values but an inverse correlation is expected since soil adsorption of pesticides is favoured by organic carbon.
SYSCOR shows a notably low sensitivity on \( \log K_{ow} \), \( DT50_{soil} \) and solubility particularly if the values of these variables are increased. The range of changes in exposure values does not exceed +10% and -1%, respectively. On one hand this low sensitivity is due to the above mentioned possibility of weighting scoring variables by breakpoint setting and assigning number of scoring categories (see sensitivity analysis of ADSCOR above). SYSCOR offers only the possibility of three scoring categories for each variable accounting for a small scoring range from 0 to 2. On the other hand SYSCOR uses a synergistic scoring system which likely has to be revised to optimise weighting of different variables.
4.2.3 Summary of findings from sensitivity analysis

The following aspects became obvious through this simple form of sensitivity analysis:

- REXTOX is mainly driven by both, pesticide use specific variables such as the *amount of pesticides applied, spray drift buffer width, and spray drift compliance* and environmental variables such as *water index* and *water depth*.

REXTOX likely overestimates the effect of spray drift buffer in comparison with the weighting of the runoff buffer. Clearly, the loss of pesticides via spray drift is given too much weight compared to loss via runoff.

- ADSCOR gives high weight to the pesticide use specific variable *area treated*. The *buffer compliance* by farmers drives the indicator remarkably, because it is the compliance, not the buffer size which is seen as the crucial aspect in connection with this water protective measure.

ADSCOR considers *log K_{ow}* twice within the scoring procedure accounting for bioaccumulation and runoff potential of pesticides. We suggest to reconsider the integration of the bioaccumulation process carefully. An appropriate integration of such a process may likely require a sub-model.

- SYSCOR, as recognized also at the final meeting of the OECD pilot project participants in October 2001, needs to be revised prior to use.

4.3 Exemplary calculations and scenarios

To illustrate the behaviour of the indicators, some exemplary calculations were carried out. In the following relative contributions of single crops or pesticides to the overall risk, calculated with actual use data, as well as scenarios based on theoretic assumptions are presented. For all calculations the short term indices of ADSCOR and REXTOX were considered only. The risk indices for all three target organisms (algae, daphnia and fish) were added up. All calculations were made on the basis of 1998 use data. Some pesticide properties, needed in the discussion of the results, are listed in appendix of Chapter 4.

SYSCOR was not included, because it was still under development and the results are hardly comprehensive.

4.3.1 Relative contributions to overall exposure and risk

Table 4.1 shows which crops or pesticides contribute most to the total risk. The three most important crops or pesticides are listed.
Table 4.1: Relative contribution of crops or pesticides to the overall exposure or risk.

<table>
<thead>
<tr>
<th>Region</th>
<th>ADSCOR</th>
<th>REXTOX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure/Risk index</td>
<td>Exposure/Risk index</td>
</tr>
<tr>
<td></td>
<td>ADSCOR</td>
<td>REXTOX</td>
</tr>
<tr>
<td></td>
<td>Exposure/Risk index</td>
<td>Exposure/Risk index</td>
</tr>
<tr>
<td>Greifensee</td>
<td>Wheat (35%)</td>
<td>Rapeseed (36%)</td>
</tr>
<tr>
<td></td>
<td>Grassland (19%)</td>
<td>Oat (18%)</td>
</tr>
<tr>
<td></td>
<td>Corn (18%)</td>
<td>Wheat (14%)</td>
</tr>
<tr>
<td>Baldeggersee</td>
<td>Wheat (35%)</td>
<td>Rapeseed (34%)</td>
</tr>
<tr>
<td></td>
<td>Barley (28%)</td>
<td>Corn (34%)</td>
</tr>
<tr>
<td></td>
<td>Corn (19%)</td>
<td>Wheat (11%)</td>
</tr>
<tr>
<td>Murtensee</td>
<td>Wheat (55%)</td>
<td>Rapeseed (54%)</td>
</tr>
<tr>
<td></td>
<td>Barley (17%)</td>
<td>Potato (13%)</td>
</tr>
<tr>
<td></td>
<td>Corn (8%)</td>
<td>Wheat (12%)</td>
</tr>
<tr>
<td>Greifensee</td>
<td>Dicamba (6.75%)</td>
<td>Lambda-Cyhalothrin (59%)</td>
</tr>
<tr>
<td></td>
<td>Thifensulfuron-methyl (5.25%)</td>
<td>Pendimethalin (5%)</td>
</tr>
<tr>
<td></td>
<td>Mecoprop-P (5%)</td>
<td>Mevinphos (5%)</td>
</tr>
<tr>
<td>Baldeggersee</td>
<td>Dicamba (4.9%)</td>
<td>Bifenthrin (34%)</td>
</tr>
<tr>
<td></td>
<td>Pendimethalin (4.3%)</td>
<td>Fonofos (28%)</td>
</tr>
<tr>
<td></td>
<td>MCPA (4.25%)</td>
<td>Pendimethalin (14%)</td>
</tr>
<tr>
<td>Murtensee</td>
<td>Glyphosate (4%)</td>
<td>Bifenthrin (17%)</td>
</tr>
<tr>
<td></td>
<td>Isoproturon (3%)</td>
<td>Cypermethrin (14%)</td>
</tr>
<tr>
<td></td>
<td>2,4-D (2.5%)</td>
<td>Terbufos (11%)</td>
</tr>
</tbody>
</table>

Discussion of relative contribution of crops

Exposure values in ADSCOR are primarily driven by the basic area treated (BAT). If exposure is aggregated per crop, BAT is summed up over all applications. Hence, the actual determining factor is the product of BAT times the number of pesticides applied. In contrast, REXTOX exposure is determined by the totally applied amount of pesticides (product of cumulative area treated (CAT) and the actual dose rate (ADR)). In Greifensee und Baldeggersee the ranking of crops, counting the most for exposure, is almost identical. Noticeably permanent grassland is on rank three in Greifensee. Although only a minor part of
grassland is treated with pesticides, it contributes substantially to the overall exposure due to its large area (almost 60% of agricultural land). In Murtensee REXTOX gives higher weight to potato and sugar beet, which are not the most important crops in terms of land use, but are very intensive cultures. In principle, the intensity and the areas of treatment are the controlling variables in both indicators.

Not only exposure but also the risk indices calculated by REXTOX are predominantly driven by the totally applied amount. In general, the crops contributing most to the overall risk are the same as those, contributing the most to overall exposure (barley is in Murtensee and Greifensee on the 4th rank considering exposure, instead on 3rd). Pesticide properties, namely toxicity, led to minor changes in ranking, but did not significantly prevail the applied amount. Hence, REXTOX in general indicates the biggest crops (in terms of pesticide and/or land use), as the most risky. The calculations are in principle accordance with expert opinions.

Surprisingly, ADSCOR identified rapeseed as the most risky crop in all three regions, although rape is a minor crop (less than 10% in Greifensee and less than 3% in Baldeggersee and Murtensee, of total pesticide application). Looking at the pesticide mix used in rapeseed, three insecticides with exceptionally high daphnia and fish toxicity stand out (namely bifenthrin, lambda-cyhalothrin and cypermethrin; for LC50 values see appendix of chapter 4). Although all these pesticides are used in small amounts, they determine the overall risk. Two reasons, associated with the construction of ADSCOR, can be identified: a) In ADSCOR all variables, except the basic area treated (BAT) and toxicity, are scored. The scoring procedure can be interpreted as compression of the exposure scale, where as the scale for toxicity stays open. This results in a much higher weight of toxicity as compared to REXTOX. b) The fact, that ADSCOR is more sensitive to BAT than to the applied amount, amplifies the importance of rapeseed. (See paragraph 4.3.2 for detailed explanation.)

**Discussion of relative contribution of pesticides to overall risk**

As denoted above, the main driving force of REXTOX exposure value is the applied amount. As a consequence the compounds contributing the most to the overall exposure are those with the highest usage. As observed for crops, other properties caused only little changes in ranking. As the most risky pesticides REXTOX identifies compounds most utilized as well as very toxic substances, which are used moderately. Both, toxicity and applied amount are risk determining factors.

Under ADSCOR the pesticides contributing the most to the overall exposure are those used on the widest area (for all regions the exposure top 3 pesticides were ranked under the first 7 considering BAT). As for crops, the risk of individual pesticides heavily depended on toxicity. Also with regard to single pesticides, toxicity is obviously more weighted than in REXTOX. In general the most risky substances feature very low LC50 values, but are applied
in very small or moderate amounts (exceptions: mevinphos in Greifensee and pendimethalin in Murtensee, are both used on large area and are relatively toxic).

4.3.2 Effect of use data resolution in ADSCOR

ADSCOR is not very sensitive to the applied dose rate, which is a scoring variable, but depends linearly on the treated area, which is used as multiplier (see paragraph 4.2). Since use data are not resolved on a field level, but only for each crop in a region, pesticides are mainly weighted by the total area of the crop and not by the actually applied amount. To prevent such artefacts, ADSCOR would demand much more detailed use data, which can hardly be implemented. The following exemplary calculation illustrates this feature.

Example for lambda-cyhalothrin application in rapeseed: In 1998 in the Greifensee region a total amount of 0.43 kg lambda-cyhalothrin was applied in rapeseed, the total area of rape was 162 ha. For indicator use data it was assumed, that all rape fields were treated uniformly, hence an average applied dose rate of 0.0027 kg/ha was used (data set A in Table 4.2). Since the recommended dose rate for lambda-cyhalothrin is about 0.008 kg/ha [32] it is likely, that only a part of all rape fields was treated. Hence, data set B (Table 4.2), where only 60 ha were treated with lambda-cyhalothrin, yielding a dose rate of 0.0072 kg/ha is more plausible. Although the totally applied amount stays the same, the ADSCOR risk index (aggregated over the total rape area and all pesticides used in rape) decreased remarkably, due to its high sensitivity to area treated (BAT). (Note: the remaining use data for rapeseed were not changed in this example!)

Tab 4.2: Effect of level of detail in use data

Example for the application of lambda-cyhalothrin in rapeseed. Values for 1998, Greifensee, aggregated for all rapeseed fields. For further explanation see text above.

<table>
<thead>
<tr>
<th>Data set</th>
<th>Area treated with lambda-cyhalothrin [ha]</th>
<th>Applied dose rate [kg/ha]</th>
<th>Total applied amount [kg]</th>
<th>ADSCOR Risk index aggregated for rapeseed</th>
<th>REXTOX Risk index aggregated for rapeseed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>161.8</td>
<td>0.00267</td>
<td>0.432</td>
<td>2525602*</td>
<td>158*</td>
</tr>
<tr>
<td>B</td>
<td>60</td>
<td>0.0072</td>
<td>0.432</td>
<td>1528827*</td>
<td>158*</td>
</tr>
<tr>
<td>Change</td>
<td>-63 %</td>
<td>+170 %</td>
<td>none</td>
<td>-40 %</td>
<td>none</td>
</tr>
</tbody>
</table>

(SYSCOR: no shift)

Note: the absolute values of the risk indices are given, a direct comparison between the different indicators is not possible.

4.3.3 Scenario 1: Substitution of atrazine by glyphosate in corn

For scenario calculation it was assumed, that atrazine in corn was totally replaced by glyphosate. The applied dose rate was kept constant (1 kg/ha, one treatment per year). Both was calculated, the change of exposure and risk considering only 1 hectare corn (Table 4.3), as well as the shift concerning the overall exposure/risk of a whole region (Table 4.4).
Table 4.3: Change of exposure and risk index for 1 ha corn, treated with glyphosate instead of atrazine.

<table>
<thead>
<tr>
<th>Region</th>
<th>ADSCOR change in % for 1 ha</th>
<th>REXTOX change in % for 1 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure Risk index</td>
<td>Exposure Risk index</td>
</tr>
<tr>
<td>all</td>
<td>none -96</td>
<td>+20 to +24</td>
</tr>
</tbody>
</table>

(SYSCOR reacts similar as REXTOX)

Table 4.4: Change of exposure and risk index for each region, caused by substitution of atrazine by glyphosate. (Aggregation of values over all crops and pesticides.)

<table>
<thead>
<tr>
<th>Region</th>
<th>ADSCOR change in % for entire region</th>
<th>REXTOX change in % for entire region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure Risk index</td>
<td>Exposure Risk index</td>
</tr>
<tr>
<td>Greifensee</td>
<td>none -1.8</td>
<td>+2.2</td>
</tr>
<tr>
<td>Baldeggese</td>
<td>none -0.9</td>
<td>+3.0</td>
</tr>
<tr>
<td>Murtensee</td>
<td>none -0.3</td>
<td>+0.8</td>
</tr>
</tbody>
</table>

(Shifts in SYSCOR were slight, all changes <0.5%)

The distinct decrease of the risk indices is mainly related to the lower algal toxicity of glyphosate compared to atrazine by factor 30. (Note: If only one pesticide application on 1 hectare is calculated, the relative importance of toxicity variation is the same for ADSCOR and REXTOX.) The relative change of overall risk is smaller for Murtensee than for Greifensee and Baldeggese, which can be explained with the relative importance of atrazine in each region: in Murtensee only 5% of the total applied pesticides (61 tonnes) is atrazine, whereas in Baldeggese and Greifensee atrazine contributes 16% (of 3.3t) and 13% (of 4.9t), respectively.

ADSCOR shows no change in exposure, because for short term calculation it does not account for pesticide properties and the scaling variables (dose rate and area) were kept constant. The increase in REXTOX exposure can be rationalized by the lower K_{ow} of glyphosate compared to atrazine. From the literature we know, that glyphosate is less mobile than atrazine due to ionic interaction with soil constituents. Hence, the exposure (i.e. surface water concentrations) are expected to decrease in contrast to the indicator results. This scenario provides an illustrative example, that the use of K_{ow} as measure for mobility or runoff potential is not appropriate. The use of K_{d} values should be favoured, but is hindered by unsatisfactory data basis.

4.3.4 Scenario 2: Substitution of pirimicarb by acetamiprid

The following assumptions were made: The insecticide pirimicarb is totally replaced by acetamiprid. The applied dose rate decreases by one third: 0.17 kg/ha of acetamiprid is
applied instead of 0.25 kg/ha pirimicarb. Table 4.5 shows the results of these scenario calculations for 1 ha rapeseed treated with acetamiprid instead of pirimicarb.

**Table 4.5:** Change for exposure/risk index concerning 1 ha rapeseed treated with acetamiprid instead of pirimicarb.

<table>
<thead>
<tr>
<th>Region</th>
<th>ADSCOR Change in % for 1 ha rapeseed</th>
<th>REXTOX Change in % for 1 ha rapeseed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure Risk index</td>
<td>Exposure Risk index</td>
</tr>
</tbody>
</table>

(SYSCOR: Exposure -5.7%, RI -99.99%)

Since in the reference year 1998 only two applications of pirimicarb in the region Murtensee are documented, the change in the entire region is negligible (<1%).

The exposure reduction in both indicator models was related to the lower application rate. The daphnia toxicity of acetamiprid is lower by a factor of $10^4$ compared to pirimicarb, yielding a respective decrease in risk indices, illustrating once more the importance of toxicity values. Focussing on aquatic risk, both indicators produced reasonable results, but it was asserted by experts, that pirimicarb nevertheless should be favoured, because of its distinctly lower toxicity for beneficial insects.

### 4.3.5 Scenario 3: Band application in corn

Assumption: Band application in corn leads to a reduction of the applied dose rate of atrazine and metolachlor by two thirds as compared to conventional application.

**Table 4.6:** Change of exposure/risk index related to 1 ha corn, treated with atrazine by band application as compared to conventional treatment. (Note: only atrazine is considered!)

<table>
<thead>
<tr>
<th>Region</th>
<th>ADSCOR Change in % for 1 ha corn (only atrazine)</th>
<th>REXTOX Change in % for 1 ha corn (only atrazine)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure Risk index</td>
<td>Exposure Risk index</td>
</tr>
<tr>
<td>all</td>
<td>none none</td>
<td>-67 -67</td>
</tr>
</tbody>
</table>

**Table 4.7:** Change of overall exposures/risk indices initiated by band application. (Note: the dose rates for atrazine and metolachlor were assumed to be reduced.)

<table>
<thead>
<tr>
<th>Region</th>
<th>ADSCOR Change in % for entire region</th>
<th>REXTOX change in % for entire region</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposure Risk index</td>
<td>Exposure Risk index</td>
</tr>
<tr>
<td>Greifensee</td>
<td>-0.3 -0.1</td>
<td>-7 -11</td>
</tr>
<tr>
<td>Baldeggersee</td>
<td>-0.3 -0.1</td>
<td>-9 -10</td>
</tr>
<tr>
<td>Murtensee</td>
<td>-0.2 none</td>
<td>-3 -3</td>
</tr>
</tbody>
</table>

(SYSCOR: no changes in exposure or risk index)
The reaction of REXTOX in this scenario is obvious and reasonable (for differences between regions see discussion of scenario 1). As discussed before, ADSCOR reacts only slightly to changes in dose rates. If only atrazine application to 1 ha is considered (Table 4.6), ADSCOR does not show any effect in exposure or risk, although, the reduction of dose rate is remarkable. This no-effect is caused by the actual breakpoint setting that provides no change in scoring class for this particular reduction in dose rate. This scenario illustrates, that breakpoint setting is critical and may provide misleading results, especially on low aggregation levels.

4.3.6 Runoff and spray drift in REXTOX

The model REXTOX considers runoff (LRO) and spray drift (LSD) as entry pathways of pesticides into surface waters (see Chapter 2). Spray drift is relatively high weighted compared to runoff (see Chapter 4.2). It is assumed, that the precipitation amount within the first three days after application is determining runoff. Table 4.8 shows the ratio of runoff to spray drift for different rain intensities. The calculations consider whole regions and are aggregated over all pesticides.

<table>
<thead>
<tr>
<th>Description of rain event</th>
<th>Region</th>
<th>Precipitation [mm]</th>
<th>LRO/LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average rain event during application period</td>
<td>all</td>
<td>8.1-8.5</td>
<td>0.07-0.11</td>
</tr>
<tr>
<td>Worst-case scenario (realistic)</td>
<td>all</td>
<td>30</td>
<td>0.28-0.45</td>
</tr>
<tr>
<td>Worst-case scenario (not realistic, the rain amount corresponds to the average monthly precipitation)</td>
<td>all</td>
<td>100</td>
<td>0.64-1.1</td>
</tr>
</tbody>
</table>

REXTOX assumes spray drift as main entry pathway. Even in case of heavy rain events spray drift exceeds run off. Up to now, only little research was done to compare the importance of runoff vs. spray drift. But nevertheless, from recent monitoring projects we know, that under typical conditions in Switzerland runoff is the main entry pathway into surface waters considering proper agricultural pesticide use. Pesticide concentrations in rivers and lakes are, in general, strongly related to rain event intensities [24, 33, 34]. In the study of Bach and co-workers [35] it was estimated that spray drift in Germany was less than 25% of the total pesticide input into surface waters. According to expert opinions REXTOX clearly overestimates the importance of spray drift (or underestimates that of runoff). Correction of this problem would require a recalibration of REXTOX and probably even further research. (Note: Enhancing runoff weight would also increase the importance of site variables and pesticide properties.)
4.3.7 Summary of findings from exemplary calculations and scenarios

Summarizing the results from example and scenario calculations, the following conclusions can be drawn:

- For ADSCOR risk indices, toxicity is of enormous importance. Overall risk can be determined by single pesticides with high toxicity, even if the applied amount is minor. Toxicity is much higher weighted in ADSCOR than in REXTOX, due to compression of the value range of other parameters by the scoring process.

- ADSCOR risk indices and exposure values are dependent on the level of detail of use data. Adding up crops on a regional level may produce artefacts (overestimation of the risk of compounds used at low doses on few fields).

- Breakpoint setting is critical and not simple. Due to breakpoints misleading results may be generated, if scoring indicators are used on low aggregated levels.

- For active ingredients which are sorbed to soil constituents by processes other than hydrophobic partitioning, the estimation of K_d from K_{ow} is not appropriate and may yield misleading results.

- REXTOX clearly overestimates spray drift compared to runoff. Recalibration is inevitable.

4.4 Comparison with monitoring data

All three indicators express risk as exposure (direct value or scores):toxicity ratio. Hence, the pesticide exposure ranking should qualitatively be related to monitoring data in surface waters. Pesticides, showing highest exposure values in the indicators are expected to occur in environmental samples at high concentrations.

A lake can be seen as an integrator of all pesticide inputs within a catchment region over time. Therefore concentrations measured in lakes should be represented by long term exposure indices, whereas concentrations in rivers should rather be related to short term exposure indices. The meaningfulness of comparing indicator and measured concentrations is mainly determined by the availability of monitoring data (pesticide selection and time range, see below). Other entry pathways than regular agricultural use of pesticides may contribute significantly to the real overall concentrations which, of course is not reflected by the indicators. Furthermore there has to be considered, that the indicators are not designed for catchment area scenarios. Because each lake basin has its own hydrology that affects the actual concentrations, regions have to be treated separately. The relative abundance of pesticides within a lake should nevertheless be represented by the indicators. To compare monitoring data from rivers with short term risk indices, the use of pesticide within the particular subcatchment should be known. In general these data are not available. Despite
these limitations, comparing measured concentrations with indicator results is a strong tool in the validation procedure.

4.4.1 Availability of monitoring data

Within the scope of the national program «Evaluation of Eco-measures in Agriculture», several pesticides in five Swiss lakes (including the three regions Greifensee, Baldeggersee and Murtensee, see Chapter 3) are monitored regularly throughout the year since 1997. The active ingredients included in that study are mainly herbicides and some fungicides (total of $\approx 30$ compounds, of which $\approx 10-12$ are regularly detected in the lakes). For further information and results of the monitoring program see the respective reports [23, 24, 30].

As the use data for subcatchment areas is hardly available the presented comparison of monitoring data with indicators’ exposure values is only made on the base of data from Lake Greifensee (for details referring to regional particularities see Chapter 3).

4.4.2 Procedure

12 pesticides (active ingredients respectively) were taken into account in the comparison (Table 4.9). They were monitored in Lake Greifensee in 1998 and were also identified in the regional 1998 use data (see Chapter 3). Seasonal peaks of pesticide concentrations in the lake occur but the seasonal time scale is not considered within the indicators. As a result we took only annual average concentrations into account whereby only values from 0 to 5m in the water column were considered. The average measured concentrations were normalised by assigning «1» for the highest and relatively lower values to the remaining 11 pesticides (Figures 4.6 and 4.7).

Table 4.9: Applied amounts of monitored pesticides

The measured concentrations reflect an annual average value in Lake Greifensee in 1998 at 0-5m depth (measurements: research group for Water and Agriculture at EAWAG). The number for the amount applied were taken from the use data survey in region Greifensee in 1998 (see Chapter 3).

<table>
<thead>
<tr>
<th>Pesticide (active ingredient)</th>
<th>measured avg. conc. [ng/L]</th>
<th>total amount applied [kg]</th>
<th>Pesticide (active ingredient)</th>
<th>measured avg. conc. [ng/L]</th>
<th>total amount applied [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrazine</td>
<td>80.3</td>
<td>633</td>
<td>Metolachlor</td>
<td>1.6</td>
<td>45</td>
</tr>
<tr>
<td>Terbutylazine</td>
<td>23.0</td>
<td>8</td>
<td>Bifenox</td>
<td>n.d.</td>
<td>8</td>
</tr>
<tr>
<td>Isoproturon</td>
<td>10.3</td>
<td>742</td>
<td>Chlortoluron</td>
<td>n.d.</td>
<td>36</td>
</tr>
<tr>
<td>Mecoprop-P*</td>
<td>9.7</td>
<td>200</td>
<td>Alachlor</td>
<td>n.d.</td>
<td>38</td>
</tr>
<tr>
<td>Dimethenamid</td>
<td>8.2</td>
<td>167</td>
<td>Metamitron</td>
<td>n.d.</td>
<td>26</td>
</tr>
<tr>
<td>2,4-D</td>
<td>5.3</td>
<td>23</td>
<td>Metazachlor</td>
<td>n.d.</td>
<td>20</td>
</tr>
</tbody>
</table>

*considered are only 50% of effective measured R-Mecoprop as about 50% of the input is not due to agricultural use but to leaching from bituminous roof sealing membranes, which contain a precursor of Mecoprop-P [36].

n.d. = not detected
The normalised monitoring data is compared with long-term scaled exposure values of ADSCOR and REXTOX. To allow comparison of long-term exposure values produced by indicators with monitoring data on the same scale, exposure values were normalised. Thereby, the highest long-term exposure value within the 1998 Greifensee data set was given the value 1.

However, out of 79 pesticides used in 1998 in that region 18 were not considered due to missing DT<sub>50</sub>,<sub>water</sub> values (see Chapter 3) which are necessary to calculate long-term exposure values in REXTOX. Hence, the normalised values of the 12 pesticides to be compared with monitoring data reflect their relative position within the order of totally 61 pesticides. SYSCOR was not included in this comparison due to its need to be revised (see Chapter 1 and 4.2.3).

Finally, the weighted ranking of selected pesticide concentrations in the lake, their amount applied, and their regional aggregated exposure values calculated by REXTOX and ADSCOR, respectively, were compared.

4.4.3 Discussion

**REXTOX**

In Figure 4.6 measured annual average concentrations (triangles) in Lake Greifensee are compared to applied amount of pesticides and respective exposure values calculated by REXTOX. What strikes out in Figure 4.6 is the difference of the weighted ranking of terbuthylazine between long-term exposure calculated by REXTOX and concentration measured in the lake. The driving force of the variable *applied amount of pesticides* in REXTOX is obvious (as already presented in Chapter 4.2.2) and the low ranking of this variable for terbuthylazine suggests that

a) other routes of exposure than agriculture are likely to be involved or

b) use data survey values (see Chapter 3) do not cover the real applied amount
Figure 4.6: Comparison REXTOX/monitoring data
Presented are the rankings of measured annual average concentrations (triangles) measured in Lake Greifensee in 1998, total amount of pesticide applied in 1998, and respective long-term exposure values calculated by REXTOX. Please note, long-term exposure values as well as values for applied amount of pesticides are normalized with respect to 61 pesticides which were used in region Greifensee in 1998. As a result, none of the displayed pesticides accounts for the normalised value «1» for long-term exposure calculated by REXTOX because another pesticide out of the 61 accounts for a higher respective value.

The exposure ranking as well as the ranking of measured annual average concentrations in Lake Greifensee do mainly correlate except for isoproturon and terbuthylazine. The exposure of the former is overestimated by REXTOX. The relative low amount of terbuthylazine applied in 1998 likely suggest that it enters through other sources than agriculture which leads to the remarkable high rank of the respective measured average concentration.

In contrast, REXTOX overestimates exposure of isoproturon and, although to a much lesser extent, of bifenox. The latter could not be detected in Lake Greifensee but REXTOX shows higher ranking of long-term exposure for bifenox compared to the detectable 2,4-D and metolachlor. Above all, the high exposure ranking of isoproturon, which is in accordance with its high applied amount, but in contrast to its low average concentration measured in the lake, is notable and needs an explanation. There is particularly one reason for this overestimate in REXTOX:

- considered DT_{50, water} from literature do not reflect the degradation processes in the environmental system «Lake Greifensee» appropriately (see Chapter 3). As shown by Gerecke [34], isoproturon is mainly eliminated by indirect photolysis and therefore only detected in relative low concentrations.

Additionally, but to a lesser extent, the relative low weighting of DT_{50, soil} and log K_{ow}, as presented in Chapter 4.2.2, may also contribute to this overestimate of exposure by REXTOX.
**ADSCOR**

ADSCOR produces an exposure ranking which is quite different to that of REXTOX (see Figure 4.7).

![ADSCOR comparison with monitoring data](image)

**Figure 4.7: Comparison ADSCOR/monitoring data**

Presented are the rankings of measured annual average concentrations (triangles) measured in Lake Greifensee in 1998, total area treated per pesticide in 1998, and respective long-term exposure values calculated by ADSCOR. Please note, long-term exposure values as well as values for area treated are normalized with respect to 61 pesticides which were applied in region Greifensee in 1998. As a result, none of the displayed pesticides accounts for the normalised value «1» for these variables because other pesticides out of the 61 account for higher respective values.

In contrast to the ranking of long-term exposure values calculated by ADSCOR and measured average concentrations ranking of the former and the area treated correlate.

Figure 4.7 shows the strong correlation between the ranking of area treated and exposure values calculated by ADSCOR but also reflects the correlation inconsistencies with measured exposure ranking. Three main aspects lead to such different ranking in ADSCOR:

- the average frequency of treatment per season was set as 1 per pesticide and crop (each crop per region has one specific amount of area treated) as mentioned in Chapter 3. This procedure leads to inadequately aggregated exposure scores if a pesticide is used several times per season on the same crop.

For example, having a pesticide applied twice, in proper ADSCOR-style there would be two scaled exposure scores calculated whereby each accounts for the area treated. For an aggregated exposure score as presented in Table 4.10 both values would be added up. If only one application per crop is considered, the aggregated score accounts just once for the
respective area treated. As a result, pesticides applied on several crops per season account for higher aggregated exposure scores such as mecoprop-P, bifenox, and isoproturon.

- *area treated* is considered as multiplier with its direct value (see Chapter 2) and, therefore, a large area may overcompensate scores assigned to a pesticide referring to its applied dose rate and physico-chemical properties. For example, Table 4.10 shows that atrazine accounts for an unscaled score of 8 whereas mecoprop-P accounts for a score of 6 referring to one crop treatment. Although the score for applied dose rate and physico-chemical properties is lower than for atrazine, mecoprop-P accounts for a higher scaled exposure score due to the larger respective area treated. Consequently, the environmental occurrence of atrazine is masked by the multiplication of scores and direct values for area treated.

- the *scoring procedure* limits the precision of an indicator. For example, ADSCOR assigns the same unscaled exposure score to atrazine and dimethenamid (see Table 4.10) although the atrazine:dimethenamid applied amount ratio is ≈ 3 (see Table 4.9 above) and a clearly different environmental behaviour of the two compounds is expected from their physico-chemical properties. For example, half-life in water for atrazine was considered with 58 days in contrast to 24 days for dimethenamid. As the breakpoint for DT₅₀,water is defined for half-lives > 60 days both end up in the same scoring category. Both account for the same aggregated exposure score as these pesticides were only applied on corn with an area treated of 919 ha.

Table 4.10: Scoring example for atrazine, dimethenamid and mecoprop-P on the base of the 1998 Greifensee use data

The number of pesticide treatments per season is a limiting factor in the calculation of aggregated scaled exposure values. A crucial aspect thereby, the area treated dominates exposure calculation.

<table>
<thead>
<tr>
<th></th>
<th>Atrazine</th>
<th>Dimethenamid</th>
<th>Mecoprop-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Rank of applied amount</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>b) Rank of total area treated</td>
<td>23 (= 919 ha)</td>
<td>23 (=919 ha)</td>
<td>4 (= 3’351 ha)</td>
</tr>
<tr>
<td>c) Number of crop treated in 1998</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>d) Assigned scores per crop treatment (unscaled)</td>
<td>8</td>
<td>8</td>
<td>6, 8, 8, 8</td>
</tr>
<tr>
<td>e) Scaled exposure score per crop (= d * basic area treated)</td>
<td>7’354 (919 ha)</td>
<td>7’354 (919 ha)</td>
<td>11’424 (1’904 ha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7’249 (906 ha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3’406 (426 ha)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>923 (115 ha)</td>
</tr>
<tr>
<td>f) aggregated exposure score (sum of e)</td>
<td>7’354</td>
<td>7’354</td>
<td>23’002</td>
</tr>
</tbody>
</table>
It is important to note that ADSCOR is designed to account for bioaccumulation (see Chapter 2). For the presented comparison with monitoring data the bioaccumulation potential of pesticides was not considered within the calculation of long-term exposure scores (i.e. all log $K_{ow}$ values were assigned a score of 0 by reducing the scoring categories to one, see Chapter 2.3, Table 2.2).

4.4.4 Summary of findings from monitoring data comparison

Comparison of indicators long-term exposure values with monitoring data is in general to be treated with caution. Nevertheless, REXTOX seems to reflect the relative portion of pesticides found in surface water quite well. In contrast, comparison of exposure scores calculated by ADSCOR to measured concentrations does not give good correlation because, besides the general broad approximative characteristics of the scoring procedure, the «mixture» of direct values and scores leads to an additional loss of precision.

The following merits of comparisons of REXTOX exposure value ranking with the ranking of monitoring data may be identified:

• results produced by REXTOX may lead to further investigations and discussions on the environmental behaviour of some pesticides if differences in monitoring and indicator results are obvious (as for isoproturon, for example).

• the ranking of exposure values may be useful for priority setting of monitoring programs. If, for example, REXTOX shows a high ranked exposure of a particular pesticide not considered in a monitoring program, a respective consideration could be interesting (although not intended by the OECD expert group, REXTOX could be useful too as add-on tool for scientific purpose).

However, if sub-regional use data is available, further comparison of river monitoring data with short-term and long-term exposure values may be made. Thereby, also ADSCOR could be considered for the purpose of refinement of breakpoints, number of scoring categories and/or increased score values for higher scoring categories to allow a more precise differentiation between categories (see Chapter 2).
5 Communication and presentation of indicator results

The way in which indicator results are communicated and presented is primarily determined by the questions to be answered. Depending on the target audience (e.g. policy makers, experts, authorities, public etc.) and the main issues (e.g. long time trends, effect of pesticide mix, importance of specific crops etc.), the presentation of the results must carefully be chosen and adapted. Because no specific scope for a potential indicator use was formulated so far by responsible Swiss authorities, some general considerations about aggregation levels and possible concepts of graphic representations of indicator results are made in the following. (Note: as Swiss use data cover only 2 years, no temporal trends can be shown.)

5.1 Level of aggregation

The OECD indicators allow very high aggregation levels. As an extreme example, one single number per year for an entire region or nation is produced (see Figure 5.1). High aggregation levels are generally only useful to analyse risk trends over several years (see Danish validation [21]) but it is not possible to rationalise trends on this level.

Because we do not have long-term use data but do have use data with regional character we analysed the indicators potential to compare regions.

Figure 5.1 shows the regional acute risk index for the three regions Greifensee, Baldeggersee and Murtensee. The regional acute risk index represents a high aggregated risk value because risk to each of the target organisms caused by all pesticides applied are combined. The main driving force is the area treated and amount of pesticide applied, respectively. Hence, region Murtensee compared to the other two regions accounts for the highest risk index as it is the most intense agricultural area covering the largest area treated and the highest amount of pesticides applied. (Note: the risk indicators are not designed for lake catchment areas and therefore do not account appropriately for the dilution processes in each region which could deliver a differentiated view on the risk situation in each region.)
Figure 5.1: Acute regional risk indices

Risk indices per region/year were normalised to the highest respective value. The acute risk index represents an aggregation across the risks to each of the three individual target organisms (i.e. algae, daphnia, fish) caused by the pesticides applied per year for the whole region.

It should be noted that the regional risk index, as high aggregated value, is mainly driven by the largest agricultural area treated, as presented by region Murtensee (see Chapter 3). It does not allow to find causes for any further differences in regional risk. However, if use data for several years is available broad trends may be presented.

The OECD risk indicator pilot project concluded, that it is essential to look behind the indicators to analyse causes for changes and differences in risk. For this purpose, low aggregation levels of risk indices have to be considered because on higher levels most causes for differences are masked. For example, instead of illustrating the aggregated regional risk index (see Figure 5.1 above), which represents the ratio of scaled exposure:toxicity (see Chapter 2) a more transparent display can be achieved by showing these values separately for each pesticide applied. This way of presentation allows tracking of single pesticides accounting for the aggregated regional aquatic risk index. By combining use data for several years «pesticide clouds» can be analysed which allow to highlight the rationales behind risk trends. It is obvious, that for the analysis and interpretation of indicator results expert knowledge is needed. Similar conclusions were made by the experts of the European CAPER project [2].

To analyse the differences of regional risk, a more detailed analysis may be done by evaluating the acute specific regional risk intensity (i.e. acute risk index/per hectare) which simply represents the risks caused by pesticides applied without consideration of their respective total area treated (see Chapter 2). Compared to the scaled risk the unscaled risk index allows to identify regions with pesticide intensive agriculture such as region Murtensee in comparison with region Baldeggersee and Greifensee (see Figure 5.2). Furthermore, a ranking of the most important crops/pesticides contributing to the regional risk index can be analysed to highlight regional differences (see Table 4.1, Chapter 4.3). The latter reveals that in region Murtensee potatoes as pesticide intense crop ranks among the first three crops.
contributing to risk whereas in the other two regions less intense crops such as wheat and corn contribute mainly to risk. The same illustrations could be of use in the analysis of risk trend changes and the analysis of risk on national level.

**Figure 5.2: Specific acute regional risk intensity**

Risk intensity indices per region/year were normalised to the highest respective value. The acute risk intensity represents an aggregation across the risks per agricultural area treated to each of the three individual target organisms (i.e. algae, daphnia, fish) caused by the pesticides applied in each region per ha and year.

Analysis of risk intensities allows to track regions with pesticide intensive crops. To analyse further details of differences in regional risk lower aggregation level of risk data is needed such as risk intensity per crop, pesticide, and individual taxa.

The presentation of unaggregated risk intensities (i.e. per pesticide) in connection with the respective area treated allows a more detailed analysis of regional risk (see Figure 5.3). This illustration allows to identify pesticides causing high risks to individual aquatic organisms and the area treated with these pesticides. If several years of use data are available, the movement of «pesticide clouds» can be analysed whereby each cloud reflects all pesticides used in one specific year. By this, for example, changes in pesticide mix in connection with the respective risk intensity and the trend of the size of area treated can be analysed.
Figure 5.3: Acute risk intensity per pesticide versus basic area treated

The acute risk intensity to algae caused by 108 and 111 pesticides applied in 1997 and 1998, respectively, in region Murtensee. The risk intensity values per pesticide represent the sum of risk intensities caused by individual applications per year. The basic area treated represent the total annual area treated per pesticide. Both values, risk intensity and area treated are normalised to the highest respective values across both years.

The consideration of several years allows to track changes in pesticide mix, risk intensity, and changes in area treated. For example, pesticide mix in 1998 shows one particular change to 1997, the application of alachlor which accounts for high risk intensity but was applied on a relative small area.

The position of pendimethalin and isoproturon within the graph are likely critical. They account for high relative risk intensity as well as area treated. As presented in Chapter 4.4, REXTOX likely overestimates the exposure of isoproturon and subsequently the risk intensity too.

Figure 5.3 displays the area treated and acute risk intensities to algae for each pesticide applied in region Murtensee in 1997 and 1998, respectively. Values are normalised to respective values across both years («1» represents the highest respective value). In region Murtensee 108 active ingredients were applied in 1997. The respective number in 1998 was 111. Figure 5.3 shows that a slight change in pesticide use occurred as alachlor was only applied in 1998. Alachlor accounts for high risk intensity but was only used on a relative small area. In both years pendimethalin represents a risk intensive pesticide. Additionally, its respective area treated is remarkable what signifies that pendimethalin accounts for a relative high scaled risk in region Murtensee (see Chapter 2).

It should be noted that the above mentioned illustrations are only examples to highlight some analysis levels and possibilities. They may also be produced on the basis of the respective scored numbers calculated by ADSCOR but with a lower degree of precision referring to relative differences between individual pesticides.
5.2 Additional illustrations

5.2.1 Apart from OECD indicators

Indicators combine use and various other properties of pesticides and weight the individual variables. Profiling of pesticide mix or single pesticides may serve as additional tool to display pesticide properties transparently (instead of mathematically combined). In contrast to the indicator, the weighting of the various properties in this case is left to the viewer. In Figure 5.4 pesticide use and properties are combined graphically. Each point stands for a pesticide, its use is aggregated over one year, the whole region and all crops. Hence, the totally applied amount is printed vs. a single pesticide property. This way of illustration opens several additional possibilities:

- Active ingredients which are outstanding in one particular property can easily be identified (e.g. lambda-cyhalothrin accounts for a high adsorption potential in soil).
- The properties of widely used pesticides can be illustrated compared to other compounds (e.g. atrazine and isoproturon are moderate concerning their half-life in soil, log Kow and daphnid toxicity, but are relatively toxic for algae.)
- Such illustrations reflect the registration procedures and extension work, which should not allow the use of pesticides with unfavourable properties in high quantities.
- The movement of such «property clouds» can be followed over time, which might provide more detailed information about changes in pesticide mix than indicators.

Obviously the analysis of such illustrations requires expert knowledge and the interpretation may vary depending on the technical background of a specialist.

In Figure 5.5 the properties of the two herbicides atrazine and glyphosate are compared in a net graph. To get all properties on one scale, it is necessary to normalize the values of each variable. For its interpretation it is important to know, how this was done. In the presented example properties of atrazine and glyphosate are only normalized to each other, hence it can only be concluded, that atrazine is more toxic, but glyphosate is degraded slowlier. If the values were normalized to all applied pesticides, we would e.g. conclude, that both herbicides are moderately toxic compared to the others. Such graphs might be used to compare pesticides or to visualise (un)favourable properties of single pesticides. Time trends could be presented in net graphs, if mean values of properties, weighted by used amounts were calculated. Evaluation of such pesticide profiles has to be done by experts.
Figure 5.4: Pesticide amounts applied in Greifensee region in 1998 vs. various pesticide properties: log $K_{ow}$ (a) half-life in soil (b) Hazard to algae, calculated as $1/LC_{50}$ (c) and hazard to daphnia (d). Each point stands for one pesticide, the applied amount is aggregated over the whole region and all crops. Note the logarithmic scale for hazard due to large ranges.
5.2.2 On the basis of REXTOX

REXTOX allows the analysis of the broad environmental importance of pesticides and pesticide groups in a specific way. The consideration of runoff potential, scaled exposure and toxicity as illustrated in Figure 5.6 allows tracking of «problematic» pesticides, e.g. pesticides which account for a high total exposure, runoff potential and comparatively high toxicity (crossing of runoff values by exposure and toxicity on the left side of Figure 5.6). Thereby, the runoff potential reflects the percent loss of pesticides via runoff calculated by REXTOX in which \( DT_{50,\text{soil}} \) and \( \log K_{ow} \) are key variables. This way of additional analysis of indicator results offers the advantage that approximated exposure values are accounted for and not only total amount of pesticides applied while analysing pesticide properties and behaviour. Thereby, the scaled exposure is a reflection of the total applied amount in combination with application specific properties such as buffer zones and application method (see Chapter 2) which are not considered within the previous illustrations where only the total applied amount is considered.

Figure 5.5: Net diagram of atrazine and glyphosate.
The single variables were normalized between the two substances.
Figure 5.6: Runoff potential, toxicity and short-term exposure of herbicides

The graph considers 57 herbicides applied in region Greifensee in 1998. All values are normalized to the respective highest value out of the 57 active ingredients. The runoff potential represents the calculated percentage of loss via runoff by REXTOX (see Chapter 2). The algal hazard stands for the ratio 1: acute algal toxicity (LC₅₀). It should be noted that a high hazard value corresponds to a low LC₅₀ value.

This way of presentation allows tracking of critical herbicides. Herbicides showing a relative high runoff potential (left side of Figure 5.6) and which account for high exposure as well as hazard values can easily be identified. Herbicides applied in region Greifensee do either show a high runoff potential but low exposure or vice versa.
6 Conclusions and outlook

6.1 Data availability

Use data
The available use data for the years 1997 and 1998 for the three regions are of sufficient level of detail and allow the aggregation of risk indices for single pesticides or crops in each region. However, at the time, the temporal and geographical availability of use data for Switzerland is insufficient to calculate national risk trends (the 1999 use data were not available until the end of the project). With exception of a few crops (namely orchards and vine), the existing data are sufficiently detailed, although estimation of reliability and precision is still missing. Sales data do not provide an alternative, because the currently available data are not detailed enough to calculate use data. Using averaged data over an entire region (which is standard practice) instead of data on single field level yields in overestimation of minor pesticides in ADSCOR because this indicator is driven by the treated area and not by the applied amount. Additionally, the aggregation of several applications of a pesticide per season and crop into one single application, leads to respective underestimations in ADSCOR because the applied frequency of treatment is used as scoring variable and not the total amount applied (see Chapter 4).

Pesticide data
Data collection is time consuming, particularly for older substances, but could be facilitated by international exchange of databases. For long term toxicity and half-life in natural waters numerous data gaps exist, which obstructed the calculation of long term indices. The remarkable variability in acute toxicity (especially for algae) and degradation rates in soil may significantly affect indicator results. Dependence of pesticide properties on pH or temperature are not considered by the indicators. Furthermore the use of $K_{ow}$ instead of $K_{d}$ values is not appropriate for compounds which interact with the soil by mechanisms other than hydrophobic partitioning.

6.2 Technical aspects of indicators
Only the main conclusions from the indicator validation are listed here. More technical details are described in the respective chapters.

Sensitivity
Exposure calculation in REXTOX and ADSCOR is primarily driven by the scaling factors «applied amount of pesticide» and «basic area treated», respectively. As a consequence, the current versions do not provide significantly more information than simpler indicators which
consider applied amount of pesticides and toxicity. Hence, depending on the questions to be addressed, the indicators, particularly REXTOX, could be simplified (focus on national use data and risk management) or need to be recalibrated and refined (focus on regional use data and risk management).

Toxicity is a main driving force in all three OECD indicators as it is considered with its direct value in the exposure:toxicity ratio. Therefore, sensitivity analysis was not performed on this variable. Nevertheless, the validity of the combination of direct values and scores reflecting an open and a compressed scale, respectively, has to be further investigated.

**Comparison with measured data**

This way of validation can only be done qualitatively, because indicators only approximate real exposure values. Relative long-term exposure values of REXTOX seem to reflect the ranking of measured surface water concentrations in Lake Greifensee quite well which might be expected according to its mechanistic concept of pesticide input into surface waters. However, further comparison should be done on the basis of a larger pesticide data set as well as short-term exposure values and stream/river monitoring data, respectively.

The comparison of exposure scores with monitoring data expectedly did not show very good agreement, because the scoring procedure leads to an additional loss of precision. Nevertheless, this comparison may be useful for a refinement of the scoring procedure, number of scoring categories and breakpoint settings.

**Relative weight of toxicity**

All indicators are inversely proportional to toxicity, but in ADSCOR the weight of toxicity is distinctly higher than in REXTOX. The ADSCOR risk index of a whole region may be driven by one single pesticide with a high toxicity, although it is used in minor amount. As only exposure, not risk can be measured, the weighting of toxicity within the risk indices remains subject to expert judgement.

**Runoff and spray drift in REXTOX**

REXTOX clearly overestimates the entry of pesticides by spray drift compared runoff. Additionally, the water protective effect of spray drift buffer zones is overestimated too in comparison with runoff buffer effects. Recalibration based on field measurements is inevitable.

**Breakpoints**

Breakpoint setting affects the exposure results in ADSCOR and SYSCOR, especially on low aggregation levels. There is no standard procedure, the break point setting is left to the user.
SYSCOR
SYSCOR was not fully developed and results are hardly comprehensible, therefore it was not considered in the main parts of our validation. Hence, no specific conclusions are made.

6.3 Use of indicators

Meaningfulness
As can be concluded from the validation results, primarily changes in the scaling variables applied dose rate or treated area and significant changes in pesticide mix toward less toxic ingredients, are reflected by the OECD indicators. Since indicators, at best, give rough estimates of risk, long time periods have to be regarded (at least 8 to 10 years). Evaluation of risk trends over shorter time ranges is not appropriate.

Interpretation
In accordance with the OECD Expert Group and the Experts from the European CAPER project [2, 9] we emphasise, the importance of a thorough analysis of indicator results. It is essential to «look behind the numbers», to identify and rationalize the reasons for observed trends or peaks. For a proper interpretation of risk indices, expert knowledge is needed. Indicators must not be used as single basis for decision making, they represent an add-on tool. Their limitations have to be carefully considered when interpreting results.

Presentation
Communication and graphic presentation of indicator results is obviously dependent on principle purpose, question formulation, and the target audience. Presentation of aggregated results includes the risk of misinterpretation or overestimation of the meaning.

The limited meaningfulness and precision of indicators has to be communicated very explicitly, e.g. while an indicator displays a 50% reduction in aquatic risk it has to be noticed that one can only conclude at best that the risk trend is declining but never can quantify the extent of changes in risk trends.

Limitations
In general, for use of each of the three OECD risk indicators, one has to be aware, that there are several limitations to consider:

• Only surface water is considered. For other environmental compartments separate indicators would be needed. Many other aspects of pesticide applications, such as danger of resistance formation or toxicity to beneficial organisms must additionally be evaluated by experts.
Not all pesticides can properly be included: e.g. detergents, mineral oil, inorganics were not considered. Metabolites and byproducts were not considered.

Only inputs through proper agricultural pesticide use are reflected by the indicators. Other entry pathways such as inputs via waste water treatment plants, storm drainage, private gardening, public or private use on roads and lawns, inappropriate operations by farmers etc., can contribute significantly to the total pesticide load to surface waters and are not considered by the indicators.

Indicators are not necessarily sensitive to measures to reduce pesticide inputs to surface waters (with exception of buffer stripes). Other measures, such as improved application methods or changes of agricultural practice (e.g. use of improved sprayers, regard on wind or weather conditions) are not taken into account by the indicators. If effects of such measures on aquatic risk should be reflected by the indicators, their impact would first have to be built into the models.

**International comparability**
Due to different data sources, format of input data, and the necessary adaptations by users (e.g. breakpoint setting), the comparison of indicator results between countries is not appropriate.

**General suitability as political tool**
Due to the need of sophisticated processing and interpretation as well as their limitations, the three risk indicators are not per se useful as political tool. For this purpose simpler indicators as used in other countries might be more appropriate. If they are nevertheless used, the previously made conclusions need careful attention.

**Suitability for Swiss situation**
The indicators allow an interpretation of use data in connection with pesticide properties on a broad scale which is a very useful aspect. As mentioned previously, each of the three indicators needs revision. However, depending on the purpose either REXTOX or ADSCOR could, in general, suit the Swiss situation. REXTOX would allow a regional risk management because region specific variables are considered. ADSCOR would allow tracking of long-term national risk trends.

During the last fifteen years the majority of Swiss farmers changed from conventional farming to integrated production (IP). This switch resulted in a significant decrease of the amount of pesticides applied. The OECD indicators would be suitable to illustrate this change, but the respective use data are not available. In the coming years, qualitative changes, rather than quantitative reduction in pesticide use are expected to affect the risk to aquatic
organisms. Therefore, indicators or tools which are not predominantly sensitive to scaling variables (area treated or amount applied) but better reflect changes of pesticide properties or agricultural practices might be additionally needed.

6.4 Next steps

**Problem formulation and decision making**
Prior to implementation, further development and evaluation of risk indicators general requirements and intended applications of indicators must be defined by the respective offices and authorities. The following points need to be addressed:

- What questions should be answered by the indicators?
- What variables and changes should be reflected, e.g. focus on regional or national risk management?
- Who are users and target audience?
- What resources can be provided for development, adaptation and processing of indicators?

**Supply of use data**
Use data are not only required for risk indicators but are also of interest for other purposes. A concept for future use data collection is essential.

**Approaches for advancing OECD indicators**
Among the OECD indicators, REXTOX seems the most suitable for the Swiss catchment area situation as it allows the highest precision level. As previously mentioned, some program adaptations are needed. For further development of REXTOX, three complementary approaches could be followed:

- Simplification means to choose rather a national than a regional adapted indicator. The present version of REXTOX shows no notable sensitivity to site variables (except water index and water depth) nor on pesticide properties, in comparison to applied amount of pesticides. A simplified version of this indicator could be produced by simple ratio calculation of applied amount:toxicity. The option of different aggregation levels would be preserved, but pesticide properties and site variables would not be used. The information obtainable from such a simple indicator, of course, is clearly limited.

The consideration of another, already existing indicator could be an alternative if simpler indicators are required. For example, the Danish risk indicator *Index of Load* represents a simple indicator used for calculating national pesticide risk (1). This indicator was compared with REXTOX by the Danish pilot project participants whereby both indicators produced similar risk trends [2, 21].
• Recalibration. The recalibration of REXTOX, namely increasing the ratio of runoff to spray drift and reweighting of pesticide and site variables might result in a more meaningful indicator. Obviously this would need further development and revalidation.

• Sophistication. The German SYNOPS, developed on the same basis as REXTOX, is a rather complex model, designed to identify hot spots and regional differences. Beside detailed site descriptions it includes the technical standards and farming practice on a regional level [37, 38]. The development of such a complex tool for specific Swiss requirements would be resource demanding and requires very detailed site and use data, linked to GIS (Geographic Information System). Such a tool would rather be a model than an indicator but would allow the evaluation of relative risk on a regional level.

Alternative tools to combine use data and pesticide properties should also be evaluated. Profiling of pesticide use (as presented in Chapter 5) could be a simple method to illustrate changes in pesticide mix.

Finally, it has to be stated that apart from a general positioning of requirements it is likely that various approaches have to be considered in risk evaluation and management as one indicator may never answer all questions raised in connection with pesticide risk.
Acknowledgments

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Literature cited


Appendix 1

Example for breakpoint setting

Reference table for breakpoint setting for applied dose rate.

<table>
<thead>
<tr>
<th>frequency</th>
<th>cumulative frequency</th>
<th>% cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>0.18</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>0.09</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.18</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>0.27</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>0.71</td>
</tr>
<tr>
<td>14</td>
<td>30</td>
<td>1.24</td>
</tr>
<tr>
<td>32.5</td>
<td>62.5</td>
<td>2.88</td>
</tr>
<tr>
<td>45.5</td>
<td>108</td>
<td>4.03</td>
</tr>
<tr>
<td>85.5</td>
<td>193.5</td>
<td>7.57</td>
</tr>
<tr>
<td>95.5</td>
<td>289</td>
<td>8.45</td>
</tr>
<tr>
<td>123.5</td>
<td>412.5</td>
<td>10.93</td>
</tr>
<tr>
<td>143</td>
<td>555.5</td>
<td>12.65</td>
</tr>
<tr>
<td>146.5</td>
<td>702</td>
<td>12.96</td>
</tr>
<tr>
<td>121.5</td>
<td>823.5</td>
<td>10.75</td>
</tr>
<tr>
<td>103.5</td>
<td>927</td>
<td>9.16</td>
</tr>
<tr>
<td>77.5</td>
<td>1004.5</td>
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<td>58</td>
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<td>1099.5</td>
<td>3.27</td>
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<td>23</td>
<td>1122.5</td>
<td>2.04</td>
</tr>
<tr>
<td>7.5</td>
<td>1130</td>
<td>0.66</td>
</tr>
</tbody>
</table>

The framed numbers indicate where breakpoints were set in ADSCOR. For example, the first breakpoint was set at the logarithmic value –2.5 indicating that each applied dose rate (ADR) ≤ 0.003 kg/ha results in a score of 0, whereas ADR > 0.003 kg/ha (but ≤ 0.012 kg/ha) results in a score of 1 (see Table 2.2, Chapter 2.3).
## Appendix 2

### Selected pesticide properties

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>log Kow</th>
<th>DT50(soil) [d]</th>
<th>Algae</th>
<th>Daphnia</th>
<th>Fish</th>
<th>Acute toxicity [mgL⁻¹]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>-0.91</td>
<td>7</td>
<td>25</td>
<td>235</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>0.8</td>
<td>2</td>
<td>100</td>
<td>1000</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Atrazin</td>
<td>2.5</td>
<td>33</td>
<td>0.043</td>
<td>87</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Bifenthrin</td>
<td>6</td>
<td>100</td>
<td>100</td>
<td>0.00016</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>Cypermethrin</td>
<td>6.6</td>
<td>112</td>
<td>3.2</td>
<td>0.00015</td>
<td>0.0007</td>
<td></td>
</tr>
<tr>
<td>Dicamba</td>
<td>-0.8</td>
<td>14</td>
<td>107</td>
<td>110</td>
<td>135.4</td>
<td></td>
</tr>
<tr>
<td>Fentin acetate</td>
<td>3.4</td>
<td>140</td>
<td>0.032</td>
<td>0.0032</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Fonofos</td>
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<td>80</td>
<td>1.5</td>
<td>0.001</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Glyphosate</td>
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<td>89</td>
<td>1.2</td>
<td>780</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Isoproturon</td>
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<td>18</td>
<td>0.03</td>
<td>507</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Lambda-Cyhalothrin</td>
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<td>56</td>
<td>1</td>
<td>0.00036</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>Mancozeb</td>
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<td>10</td>
<td>2.8</td>
<td>0.62</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td>MCPA/MCPB</td>
<td>-0.8</td>
<td>14</td>
<td>220</td>
<td>100</td>
<td>232</td>
<td></td>
</tr>
<tr>
<td>Mecoprop-P</td>
<td>-0.23</td>
<td>10</td>
<td>270</td>
<td>100</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Metamitron</td>
<td>0.83</td>
<td>35</td>
<td>0.22</td>
<td>102</td>
<td>222</td>
<td></td>
</tr>
<tr>
<td>Metolachlor</td>
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<td>20</td>
<td>0.1</td>
<td>25</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>Mevinphos</td>
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<td>8</td>
<td>10</td>
<td>0.1</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>Pendimethalin</td>
<td>5.18</td>
<td>105</td>
<td>0.0067</td>
<td>0.28</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>Pirimicarb</td>
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<td>121</td>
<td>140</td>
<td>0.005</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Terbufos</td>
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<td>10</td>
<td>0.00031</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Thifensulfuron-methyl</td>
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<td>15</td>
<td>970</td>
<td>100</td>
<td></td>
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</table>