

## **Pesticide Aquatic Risk Indicators:**

**Testing the OECD indicators REXTOX, ADSCOR and SYSCOR and the Norwegian aquatic risk indicator with estimates of use data from Norway.**

*By Erlend Spikkerud, Norwegian Agricultural Inspection Service*

# 1. Description of indicators

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## 1.1. OECD indicators

Description of the OECD indicators REXTOX, ADSCOR and SYSCOR will be found elsewhere in the technical report, and will not be repeated here.

## 1.2. Norwegian aquatic risk indicator (NARI)

### 1.2.1. Background

The Norwegian aquatic risk indicator (NARI) used in this project is part of the environmental risk indicator developed by a project group under the Norwegian Agricultural Inspection Service in 1998. In addition to the parts used here (aquatic + bioaccumulation), the environmental risk indicator includes parts for terrestrial effects, persistence and mobility. The environmental risk indicator was developed as a tool to monitor development in environmental risk to see if the different measures and recommendations under the National Action Plan to reduce risk from use of plant protection products (1998-2002) have the intended effect on risk reduction.

### 1.2.2. The indicator

Pesticides can contaminate the surface water mainly by spray drift, by surface runoff and by runoff into drainage systems.

#### Spray drift

Estimates of spray drift are based on the investigations by Ganzelmeier et al. (1995). One assumes that Good Agronomic Practice (GAP) is followed, and water depth is set to 30 cm in the calculations. The predicted initial environmental concentration (PIEC) is calculated for a 10-meter buffer zone for all the pesticides regardless of buffer zone on label.

#### Surface runoff

The basic assumption, asserted in ECPA (1995) with reference to Wauchope (1978), is that surface runoff for the majority of pesticides is less than 0.5 %. It is proposed that 0.5 % runoff from a 1.0 ha field to a 0.2 ha pond which is 1.0 m deep should be the standard scenario. Since surface runoff to a large extent is dependent on the pesticides properties, we have chosen to modify the runoff percentage as follows:

Pesticides with <i>high</i> potential for particle-bound transport:	0.5 %
Pesticides with <i>medium</i> potential for particle-bound transport:	0.3 %
Pesticides with <i>low</i> potential for particle-bound transport	0.1 %

The potential for particle-bound transport is judged according to a system based on Goss and Wauchope (1990).

**Table 1: Potential for particle-bound transport. Based on Goss & Wauchope (1990).**

Potential	Criteria
High	DT50 $\geq$ 40 days and Koc $\geq$ 1000 DT50 $\geq$ 40 days, Koc $\geq$ 500 and solubility $\leq$ 0,5 mg/l
Low	DT50 $\leq$ 1 day DT50 $\leq$ 2 days and Koc $\leq$ 500 DT50 $\leq$ 4 days, Koc $\leq$ 900 and solubility $\geq$ 0,5 mg/l DT50 $\leq$ 40 days, Koc $\leq$ 500 and solubility $\geq$ 0,5 mg/l DT50 $\leq$ 40 days, Koc $\leq$ 900 and solubility $\geq$ 2 mg/l
Medium	All other

## Runoff into drainage systems

It is possible to run mathematical leaching models to calculate concentrations in drainage pipes. Based on this and a chosen standard scenario one can calculate the concentration of pesticide in the recipient. Such calculations are however far too laborious to be built into a system as the one we present here. We have not found any simple method of calculating runoff into the drainage systems.

## Acute risk for aquatic organisms

For each of the organism groups algae/water plants, daphnids and fish, TER values are calculated for surface runoff and drift by dividing the toxicity ( $LC_{50}/EC_{50}$ ) by PIEC. The EU (Uniform Principles) has set threshold values related to TER for each of these groups. The value for acute studies on daphnids and fish is 100, while for chronic trials and for trials on algae and water plants the value is 10. For each of the groups a score A (Aquatic risk) is assigned (table 2), and the highest score is used as an indicator for the risk of undesirable effects in the aquatic environment. The index only takes account of the most sensitive type of organisms because the route of exposure is usually the same for all organisms and the tight food chain in the aquatic environment means that they are all to a large extent affected by each other. To keep the system as simple as possible no account has been taken of chronic toxicity.

**Table 2: Scores for aquatic risk based on TER-values.**

TER from acute studies with daphnids or fish	TER from studies with algae or water plants	A
>100	>10	0
10-100	1-10	1
1-10	0,1-1	2
0,1-1	0,01-0,1	3
<0,1	<0,01	4

## Bioaccumulation

The bioconcentration factor (BCF) cannot be used as a criterion on its own, but must be related to the pesticide's persistence and the rate of purification. We have chosen to use persistence data from soil studies because many pesticides lack acceptable degradation studies in water/sediment systems. The BCF for whole fish is used as a standard. The score (*B*) for bioaccumulation is obtained according to table 3. Figures in brackets give the weighting factor for the individual property and the total score is obtained by multiplying these factors together. If the BCF is not available,  $\log P_{ow}$  can be used, but in that case the column for the slower rate of purification is used. A low bioconcentration factor ( $BCF < 100$  or  $\log P_{ow} < 3$ ), very rapid purification ( $DT_{50} < 1$  day) or very rapid degradation in soil ( $DT_{50} < 1$  day) give a nil score for bio-accumulation, but are omitted from the table for clarity.

**Table 3: Scores for bioaccumulation based on bioconcentration factors, persistence and purification rate.**

	BCF: 100-1000 or $\log P_{ow}$ 3-4 (1)		BCF >1000 or $\log P_{ow}$ >4 (2)	
	Purification, $DT_{50}$		Purification, $DT_{50}$	
	1-10 days (0,5)	>10 days (1)	1-10 days (0,5)	>10 days (1)
Persistence in soil, $DT_{50}$				
1-10 days (0,5)	0,25	0,5	0,5	1
10-60 days (1)	0,5	1	1	2
60-200 days (1,5)	0,75	1,5	1,5	3
>200 days (2)	1	2	2	4

## Active ingredient's aquatic risk index

An aquatic risk index ( $A_{ri}$ ) is calculated for each active ingredient in each individual product. In this way an active ingredient that is used in several products can have several aquatic risk indices depending on the application rate and type of use.

$$A_{ri} = (A + B)^2$$

Ari = Aquatic risk index

A = Score for undesirable aquatic effects

B = Score for bioaccumulation

In the calculation of scores, values that may have an interval of several powers of ten are converted to a simple geometric progression from 0 to 4. The range between highly worrying values and harmless values is thus compressed. To compensate for some of this compression, the square of the sum of the scores is taken to obtain a better spread of values between pesticides with high environmental risk and chemicals with low environmental risk.

### Index for monitoring of changes over time

To obtain an aquatic risk index which can be used to monitor changes over time, the aquatic risk index ( $A_{ri}$ ) for each individual active ingredient in each product is multiplied by the area on which the product is used a particular year. These indices are added up to obtain a cumulative aquatic risk index for monitoring over time.

$$\text{Norwegian aquatic risk indicator} = A_{ri1} \text{ area}_1 + A_{ri2} \text{ area}_2 + \dots + A_{rij} \text{ area}_i$$

## 2. Estimating use data from sales data

As part of a new tax system implemented in 1999, the Norwegian Crop Research Institute defines a Standardised Area Dose (SAD) for each plant protection product (PPP). SAD equals the maximum application rate (grams or ml per hectare) in the dominating crop(s) for which the PPP is approved.

Norway have had annual sales data on product level for several decades. A major drawback with sales data compared to real use data is that the sales data refer to quantities sold by the importer to the retailer or distributor and are therefore a rather uncertain measure of the quantities actually used in a particular year. Some of the variations from year to year can be due to commercial arrangements of the importers or farmers as well as to changes in actual use. The statistics nevertheless give a good picture of use in a slightly longer time perspective. This can be seen in figure 1 below, where the overall trend is a reduction in tonnes imported, but most of the humps in the curve can be connected to changes in the tax system. In interpreting the trends of the risk indicators it is therefore very important not to attach too much importance to the single year but to look at several successive years together.

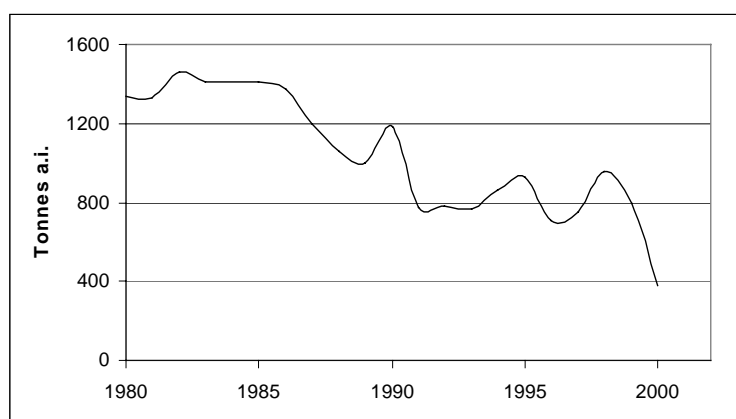


Figure 1. Norwegian sales data in tonnes active ingredients for the years 1980-2000.

The Cumulative Area Treated (CAT) needed in the indicators, could easily be estimated by combining sales data with SAD. This method of estimating CAT was chosen because of its simplicity when already having SAD. A problem with this estimation method is that the cumulative area treated is underestimated, since many farmers use lower application rates than the maximum label rate. Another problem is that it is impossible to differentiate

use in different crops on a detailed level, since the application rate and method in a crop is not registered if the crop is not a dominating one.

Norway has started a project to collect use data from 2001, which will make the indicator results more reliable in the future.

### 3. Input data

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#### Use data

Sales data for the years 1996 to 2000 were used in running the indicators since they were easily available in database. Going further back would be very time-consuming.

The cumulative area treated were calculated for all pesticides, and the top 10 herbicide, fungicide and insecticide active ingredients were chosen for each of the years 1996-2000. Seed treatment pesticides were not included, since their contribution to water pollution were considered minimal. If an active ingredient was among the top 10 one of the years, it was followed all the years. All pesticide products containing the active ingredient were used. In addition, 3 growth regulators were included. These 56 active ingredients cover 64 % of the total cumulative area treated, 79 % of total sales (kg) and 44 % of all active ingredients used in Norway.

A problem with using the years 1996-2000 is the consequences of the implementation of a new tax system for plant protection products in 1999. This new tax is differentiated according to the potential risk to human health and the environment, and the PPPs with the highest potential risk receive the highest tax. The announced implementation in 1999 and increase in 2000 led to a high import in 1998 and 1999 to avoid the new/increased tax and a very low import in 2000. To minimise this problem, the sales data for each year used in the indicators were taken as the average of three consecutive years (as an example, the sales for 1998 was the average of the years 1997 to 1999). In this way some of the variations due to other factors than actual use can be reduced.

#### Regions/crops

Only one region was used, since the use data are estimated from national sales data, not regional data. All major crops in Norway are represented, but the use data estimation method makes it impossible to differentiate use in different crops on a detailed level, since use in a crop is not registered if the crop is not a dominating one.

#### Pesticide properties

56 active ingredients were used in the indicators. German data on pesticide properties were used for 37 of these, but 19 were lacking from the German list, so we had to use Norwegian data. The indicators were only run with focus on short-term effects (mainly because of missing long-term data).

#### Breakpoints

Before setting the breakpoints, the pesticides were sorted on each parameter. Then the breakpoints were set at values that distributed the pesticides more or less equally in the different groups.

### 4. OECD software

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The OECD aquatic indicator software was easy to install and run. The guidance document was easily understandable and addressed all the important points. The major part of the pilot project was formatting the input data, not running the indicators or getting to know the software. Our only suggestion for improvement is that the software should use actual K<sub>oc</sub>-values if the column is filled in the pesticide properties table. Estimations from log K<sub>ow</sub> gives a poor estimate when other factors than organic matter are important for adsorption.

## 5. Results

### 5.1. Unscaled indicators

The trends for the unscaled REXTOX and ADSCOR are the same, a slow decrease for the years 1996 to 2000, with toxicity to Daphnia contributing far more to the total risk than toxicity to algae and fish (Fig. 2 and 3). This is also the case for NARI. SYSCOR does not have an unscaled version, but the scaled version of SYSCOR (Fig. 4) shows trends similar to the unscaled version of REXTOX, ADSCOR and NARI (Fig. 5).

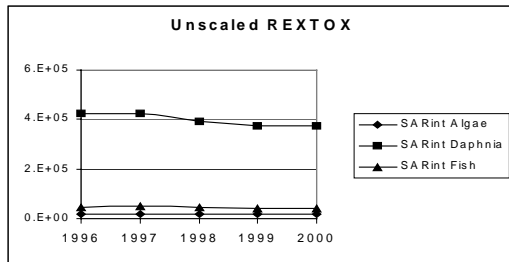


Figure 2: Unscaled results for REXTOX.

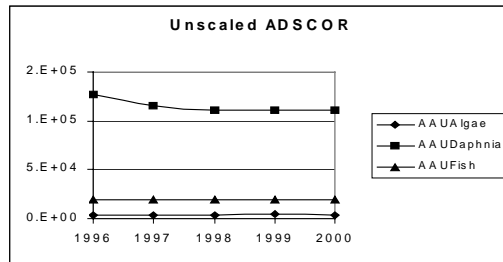


Figure 3: Unscaled results for ADSCOR.

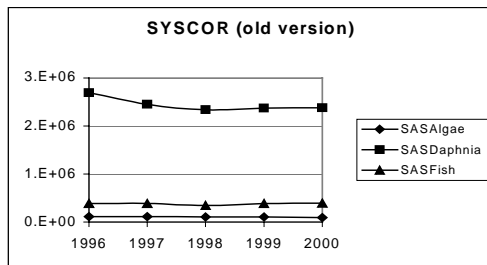


Figure 4: Scaled results for SYSCOR.

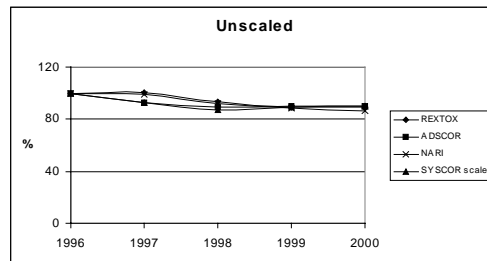


Figure 5: Normalised unscaled results for REXTOX, ADSCOR and NARI and scaled for SYSCOR.

### 5.2. Scaled indicators

The trends for the scaled REXTOX and ADSCOR are an increase in risk from 1996 to 1998 and then a marked decrease to 2000 (Fig. 6 and 7). The same is the case for NARI and the curve for cumulative area treated (Fig. 8). As mentioned above, SYSCOR does not show the same marked trend, but is rather flat.

Figure 6: Scaled results for REXTOX

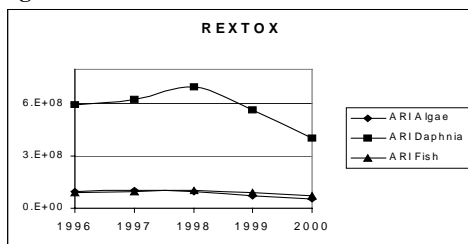
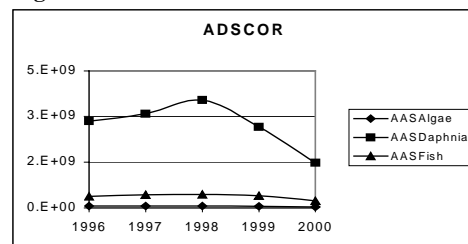


Figure 7: Scaled results for ADSCOR



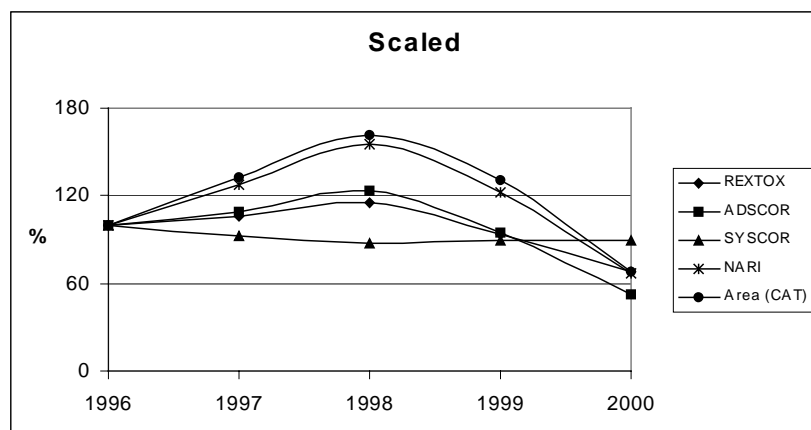


Figure 8: Normalised scaled results of all four indicators and the cumulative area treated (CAT).

### 5.3. Top 10 pesticides

Pyrethroids and phosphorous insecticides dominate the top 10 list of both the unscaled and the scaled versions of the indicators. This can explain the very high influence of toxicity to *Daphnia* compared to the toxicity to algae and fish. Esfenvalerate is the most influential active ingredient in all four scaled indicators, and there are considerable overlaps in the other top 10 active ingredients (Table 5). The top 10 list for cumulative area treated (Fig. 6) show almost no overlap with the indicators, and is dominated by herbicides.

Table 4: Top 10 pesticide active ingredients for the unscaled versions of the indicators.

REXTOX	%	ADSCOR	%	NARI	%
chlorfenvinphos	47.5	esfenvalerate	50.2	chlorfenvinphos	17.7
azinphos-methyl	31.5	chlorfenvinphos	16.8	azinphos-methyl	12.6
diazinon	8.2	lambda-cyhalothrin	10.3	esfenvalerate	9.6
fenthion	4.9	alpha-cypermethrin	8.6	fenthion	9.6
propachlor	2.5	azinphos-methyl	4.9	diazinon	7.1
esfenvalerate	1.6	diazinon	4.4	clofentezine	7.1
linuron	0.8	fenthion	0.7	lambda-cyhalothrin	7.1
prochloraz	0.5	metribuzin	0.7	alpha-cypermethrin	4.9
methiocarb	0.4	prochloraz	0.6	diquat dibromide	3.1
alpha-cypermethrin	0.4	permethrin	0.5	permethrin	3.1
Total	98.2		97.7		81.9

Table 5: Top 10 pesticide active ingredients for the scaled versions of the indicators.

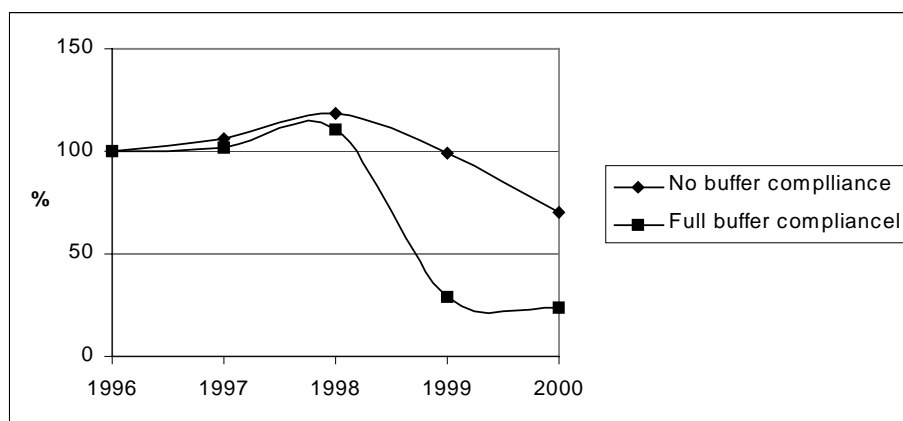
REXTOX	%	ADSCOR	%	SYSCOR	%	NARI	%
esfenvalerate	33.3	esfenvalerate	75.3	esfenvalerate	53.7	esfenvalerate	37.7
azinphos-methyl	18.4	alpha-cypermethrin	19.6	chlorfenvinphos	15.9	alpha-cypermethrin	29.2
chlorfenvinphos	16.2	lambda-cyhalothrin	3.0	alpha-cypermethrin	9.9	lambda-cyhalothrin	7.4
alpha-cypermethrin	11.6	metribuzin	0.6	lambda-cyhalothrin	8.4	fenpropimorph	4.6
diazinon	5.1	chlorfenvinphos	0.4	azinphos-methyl	3.6	diquat dibromide	3.9
propachlor	3.1	azinphos-methyl	0.2	diazinon	3.2	mancozeb	3.6
metribuzin	2.9	diazinon	0.2	metribuzin	1.1	ioxynil	3.6
prochloraz	2.0	prochloraz	0.2	fenthion	0.5	tolyfluanid	1.9
linuron	1.6	diquat dibromide	0.1	linuron	0.5	azinphos-methyl	1.4
diquat dibromide	1.3	permethrin	0.1	diquat dibromide	0.4	permethrin	1.3
Total	95.4		99.6		97.4		96.7

**Table 6: Top 10 pesticide active ingredients for the cumulative area treated**

Cumulative area treated	%
tribenuron-methyl	14.8
glyphosate	10.2
MCPA	9.2
propiconazol	6.4
alpha-cypermethrin	5.0
fenpropimorph	4.9
dichlorprop-P	4.8
ioxynil	3.9
mancozeb	3.9
chlormequat-chloride	3.5
	66.6

## 5.4. Buffer compliance

The importance of buffer zones in REXTOX is illustrated in figure 9, which show the normalised results with no buffer compliance and with full buffer compliance. The marked drop in the full buffer compliance curve in 1999 and 2000 reflects the implementation of increased buffer zones up to 30 meters in 1998. This had effect on the pyrethroids and phosphorous insecticides from 1999. In the normal running of the OECD indicators, a 50 % buffer compliance was used.



**Figure 9: Scaled REXTOX with no buffer compliance and with full buffer compliance.**

## 6. Interpretation

The indicators REXTOX, ADSCOR and NARI show the same trends, both in the unscaled and in the scaled versions. Their scaled versions are very influenced by the cumulative area treated (CAT), and a curve for CAT gives the same trend as the scaled versions of these indicators. SYSCOR gives very little weight to CAT, and does not respond like the scaled versions of the other indicators. Instead it gives a scaled trend like the unscaled trend of the others.

CAT is very influenced by variations in sales data caused by changes in our tax system (stocking up in 1998 and 1999). Taking the average of consecutive years evens out the sales data curve, but maybe not enough. To get more reliable trends we need real use data, or a longer time period. It will be much easier to draw conclusions when the data for 2001 is ready, since we expect 2001 will be a more normal year, and we will also have real use data to compare with.

All four indicators identify more or less the same problem pesticides. The pyrethroids and the phosphorous pesticides dominate the top 10 lists, with esfenvalerate on the top of all the scaled lists. The trend for CAT was similar to the scaled indicators, but there was almost no overlap in the top 10 list. Since completely other pesticides drive the CAT trend, the similarity in trends should not be interpreted in favour of using CAT (or sales data) as an indicator of risk.

## **7. Examples of presentation**

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Graphs with separate lines for algae, daphnids and fish were used to show trends for different indicators (see above). They were used mainly because they already were in the distributed software, and because they give a clear picture of time trends in a way that should be easily understood by everyone. This is important, since the tracking of trends often is one of the main reasons why indicators are developed. Normalised graphs were used to compare the trends of different indicators in one figure.

A negative side of using simple graphs is that they can give you an overview, but not much more and they can even be misleading. To make a simple graph you have to use some sort of sum or average, and in this way you lose detailed information, and may hide trends going in different directions. One way of getting a better picture of what is driving the indicators, is combining the simple graphs with lists of top 10 pesticides. Top 10 tables are easily understood, and are a way of identifying problem pesticides that need more attention.

When presenting the results you may have to choose whether you are interested mainly in the overall time trends or in more detailed information on what is driving the trends. Simple graphs can be seen as a tier 1 that gives a simple overview of the total situation. Tier 2 could be a scatter plot of exposure versus 1/toxicity for each year. By comparing different years you can see if changes in use (exposure) or changes in toxicity is driving the trends. In the same plots you will probably be able to identify problem pesticides as outliers.

## **8. Observations, conclusions and lessons learned**

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The most time-consuming part of working with the indicators was formatting the use data. The procedure for estimating use data was easy to do since we already had the standardised area dose (SAD) for all pesticide products, but using sales data to estimate use is far from ideal. The variations from year to year can be dominated by factors other than changes in actual use. The use estimates nevertheless give a good picture of use in a slightly longer time perspective. In interpreting the indicator trends, it is very important not to attach too much importance to the single year, but look at several successive years together. Problems with our estimation method are that the cumulative area treated is underestimated and that it is impossible to differentiate use in different crops on a detailed level (see chapter on use estimates above).

The most difficult parts of working with indicators (once they are developed) will probably be:

- Deciding on which pesticides to include.
- Making use estimates if use data is not available. Expert judgement on use of each pesticide may be necessary.
- Deciding on standard values from often very heterogeneous environments (regions table). Since Norway only have national sales data, this was not that important except from defining a slope to make runoff important.
- Deciding on pesticide property data when there are large variations (degradation times etc.) and how to handle missing data (long-term effects).
- How to present the results.

It is important to bear in mind the overall objective of the risk indicators, and to be aware that the systems should not be used in other contexts without considering the need for modifications. Our Norwegian indicator is designed to describe the cumulative risk trend on a national level for all our pesticides, and may not always describe the characteristics of a single pesticide well. The use of risk indicator models must always be followed by a scientific evaluation, and must only be regarded as a tool for a rough estimation of risk. The indicators give relative risk, and the relation to real risk is not clear.

## 9. What to do with these (or other) indicators

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Since the OECD indicators REXTOX and ADSCOR showed the same trend as our own aquatic indicator and identified the same problem pesticides, we will probably use our own environmental indicator to evaluate risk trends as a follow-up to our National Action Plan. REXTOX and ADSCOR will be used in discussions about improvements of our own indicator.

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